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ANALYSIS OF PHASE IIA OF

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6 ANALYSIS OF PHASE IIA OF FE 43.8.

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ABSTRACT

This report ~~contains the analysis of~~ analyzes data collected from Field Experiment 43.8, Phase IIA, the ground-to-air visual detection experiment. Phase IIA was a one-sided experiment using AH-1G and OH-58 helicopters for detection at ranges from 1 to 5 kilometers by ground observers with unaided vision. The experiment provided data on the time required for a ground observer to detect an observation helicopter, an attack helicopter (AH), or an attack helicopter team (AHT) and the frequency of detection for each configuration while situated in a firing position. Independent variables tested in the experiment were range, search sector, canopy or no canopy helicopters, lateral or no lateral movement, sky or terrain background, single ship or helicopter team presentation, and for multiple pop-up tactics, elapsed time between first and second pop-up, and location of the second pop-up with respect to the initial pop-up.

The data gained from this experiment, when coupled with data from Phase IIB, the air-to-ground experiment, will produce information required to develop helicopter employment tactics. Detection time determined from the analysis of the data will be used in ~~the~~ subsequent experiments as a guide for constraining helicopter pop-up times to reduce AHT vulnerability.

Letter on file

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EXECUTIVE SUMMARY

1. BACKGROUND. Field Experiment 43.8, Attack Helicopter-Daylight Offense, was planned to provide data for the scientific analysis of the effectiveness and survivability of the attack helicopter (AH) and the attack helicopter team (AHT), one AH, and one Scout helicopter. The major phases of the 43.8 experiment as originally planned are listed below:

- Phase I - Training and exploratory exercise in preparation for Phase II.
- Phase II - Side experiments designed to collect data to facilitate conduct of the Phase IV simulated combat experiment and to provide for Scout helicopter effectiveness evaluation.
- Phase III - Training and exploratory in preparation for Phase IV.
- Phase IV - A two-sided, simulated combat experiment to provide effectiveness and survivability data on use of the attack helicopter concept.

Phases I and II were completed. Phases III and IV were cancelled. Phase IIA, the ground-to-air visual detection experiment provided data on the elapsed time and frequency of unaided, ground observers to detect helicopters that employ various techniques and tactics. The experiment was conducted at Hunter-Liggett Military Reservation, California, from 15 May 1973 to 19 June 1973.

2. PURPOSE. This phase of Experiment 43.8 was performed to obtain data which can be used to develop techniques that best exploit the capabilities of attack helicopters to contribute to the success of daylight offensive operations on the mid-intensity battlefield. The data obtained in this experiment may be analyzed to devise exposure constraints for use in developing tactics to be used by the attack helicopter team.

3. OBJECTIVES.

a. Objective 1. To provide data to determine what the limits of the helicopter exposure times should be when the armed helicopter team is attempting to detect and engage defending point targets during conduct of daylight offensive helicopter antitank missions.

b. Objective 2. To provide data for use in the evaluation of the armed helicopter team vulnerability, when the armed helicopter team is conducting daylight offensive helicopter antitank missions against defending enemy forces.

c. Objective 3. To provide data on the effects of human factors, weather, and topography on player performance.

4. SCOPE OF EXPERIMENT.

a. The helicopter tactics addressed in this experiment were lateral maneuver, lateral spacing (helicopter team only), elapsed time between first and second pop-ups, second pop-up position with respect to the first pop-up position (same or 200 to 400 meter distance), range, background, and configuration; i.e., equipped with or without canopy.

b. A Scout helicopter performed pop-up at predetermined positions at ranges of 1, 2, 3, and 5 kilometers. An attack helicopter performed pop-up at a range of 3 kilometers. An AHT (one attack and one Scout helicopter) performed pop-up at 1, 2, and 3 kilometer ranges. The helicopters were equipped with canopy in all trials except for the canopy experiment.

c. A trial consisted of 10 ground observers situated so that line of sight was unobstructed from all observer positions. The helicopters remained exposed for approximately 1 minute subsequent to a search alert command, which signaled the threat observers to search their respective sector for helicopter activity.

5. SUMMARY OF RESULTS.

a. Objective 1.

(1) The maximum exposure time for the OH-58, AH-1G, and AHT could not be statistically estimated with any degree of confidence because the majority of the trials did not result in a detection, within the trial time constraint of 60 seconds.

(2) Grouping the data for each system, irrespective of trial conditions, to arrive at a crude estimate for "limits of exposure" results in a mean of 36 seconds for the OH-58, 32 seconds for the AH-1G, and 35 seconds for the AHT.

b. Objective 2.

(1) The effect of canopy removal (eliminating canopy glint) was inconclusive for the OH-58, nonsignificant for the

AH-1G (detection probability was .30), and significantly decreased the detectability of the AHT (probability decreased from .44 to .38).

(2) Lateral maneuver increased the frequency of detection for the OH-58 and AH-1G (probability increased from .30 to .57 and .30 to .64, respectively).

(3) Wide lateral spacing (greater than 500 meters) generally decreased the detectability of the AHT (the probability decreased from .55 to .44 when either helicopter was detected and .28 to .03 when both were detected).

(4) The 120° sector generally decreased the frequency of detection for the OH-58, AH-1G, and AHT (detection probability decreased from .41 to .29 for the OH-58 and .42 to .33 for the AH-1G; when either helicopter was detected the probability decreased from .60 to .50 and .19 to .09 when both were detected).

(5) The effect of background was inconclusive for the OH-58; terrain background decreased the detectability of the AH-1G and AHT (the probability of detection for the AH-1G decreased from .53 to .30; when either helicopter of the AHT was detected the probability decreased from .68 to .44 and .19 to .11 when both were detected).

(6) Changing the second pop-up position for the multiple pop-up trials decreased the detectability of the OH-58 (from .48 to .36 probability of detection), but was nonsignificant for the AH-1G (detection probability of .31).

(7) The time elapsed between pop-ups for the multiple pop-up trials was nonsignificant for the OH-58 (detection probability of .42), but decreased the frequency of detection for the AH-1G when the time elapsed was 60 seconds (a decrease of .37 to .25).

(8) The OH-58 trials conducted with the infrared suppressant paint significantly decreased the frequency of detection when compared to the frequency of detection for the standard painted helicopters (a decrease of .49 to .34).

(9) An increase in range generally decreased the frequency of detection for the OH-58 and AHT. The detection probabilities associated with the OH-58 according to range were: 1 kilometer - probability = .63; 2 kilometers - probability = .41; 3 kilometers - probability = .35; and 5 kilometers - probability = .17. The AHT detection probabilities (at least one helicopter detected) with respect to range were: 1 kilometer - probability = .93; 2 kilometers - probability = .71; and 3 kilometers - probability = .46.

c. Objective 3. Data on the effects of human and environmental factors were not available; therefore, this objective was not addressed in the report.

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1. INTRODUCTION.

a. Purpose. This data analysis report was compiled to address the objectives of Field Experiment 43.8, Phase IIA, the ground-to-air visual detection experiment. This report answers the essential elements of analysis (EEA) by using selected measures of effectiveness (MOE), collected as experiment data, in the most statistically valid and powerful techniques for analysis. The experimental matrix for each MOE is explicitly outlined in appendix A.

b. Scope of Analysis.

(1) Subsequent to a Kolmogorov-Smirnov one-sample test, which tests the null hypothesis that a random sample is from a parent normal population whose parameters are equal to those of the sample distribution, the finding was that the distribution of frequency of detection was not normally distributed and could not be transformed to satisfy appreciably the assumptions of ANOVA; therefore, nonparametric statistical techniques were applied.

(2) The analysis was separated into three distinct sections corresponding to the OH-58, AH-1G, and the AHT, respectively. The analysis within each section consisted of five sequential steps (the last two were combined across systems).

(a) Step 1, Determination of Significant Factor Effects. To determine if a significant difference existed between two levels of a factor, Fisher's exact probability test with Tocher's modification was used. Fisher's exact probability test is a nonparametric technique for analyzing dichotomous data. The test determines whether two samples of mutually exclusive data differ in proportion. The utilization of this test involved constructing a 2 x 2 table classified into "detect" and "no detect" categories for each of the two factor-level combinations that were of interest. All tests were used with a critical value based on an $\alpha = 0.10$ significance level.

(b) Step 2, Results by EEA. A summary was made by EEA of the general findings of factor effects upon the helicopter systems.

(c) Step 3, Optimum Tactics. This step consisted of applying minimax decision criteria (see appendix B) on alternative helicopter tactics to determine the optimum tactic. An optimum tactic employed by a helicopter is one that attempts to minimize its detectability while the threat force attempts to maximize the helicopter's detectability.

(d) Step 4, Conclusions on EEA. To the maximum extent possible, conclusions are drawn with respect to common EEA across helicopter systems.

(e) Step 5, Conclusions on Tactics. An attempt is made to identify optimum tactics common to all systems that result in techniques that best exploit the capabilities of attack helicopters.

(3) This report primarily addresses the effect of helicopter tactics on the frequency of detection. The distributions of detection times are not discussed (other than citing median detect times) due to the high percentage of censored data, i.e., no detections. Because of this high degree of censoring, standard techniques are not applicable from a practical point of view.

c. Description of Experiment. A total of 480 basic trials were conducted, with 475 trials (99 percent) being used in the analysis. Infrared suppressant painted helicopters were used for the primary 480 scheduled trials. All painted portions of the helicopter visible to a ground observer were painted with the special paint and included the main rotor, main rotor hub, mast, and tail boom pylon. A trial began when the observer group was issued a search alert. Each observer then searched his assigned search sector for possible helicopter activity. The helicopter(s) popped up at the end of a random elapsed time (0-3 minutes), which started when the search command was issued, and remained exposed for 1 minute (± 5 seconds). The elapsed time from occurrence of line of sight to detection was recorded and provided the basic data. For each trial 10 ground observers were situated in proximity to one another rather than in "full tactical deployment" so that line of sight to the selected pop-up points was unobstructed from all observer positions. Observer positions were separated in order to preclude interaction between observers. In addition to the basic 480 trials, 40 trials were conducted to assist in the evaluation of the effect of IR suppressant paint on the visual detection of the OH-58 helicopter. Individual trials were randomized to determine the sequence in which the trials would be conducted. Two design and one operational constraints, however, were imposed on the randomization. First, 1 and 2 kilometer trials were scheduled in the first 120 trials in order to allow for a sequential design. Second, only 50 percent of the trials to be used for the canopy versus no canopy comparison were randomized in the first 240 trials. The remaining 50 percent were scheduled in the last 240 trials to insure comparable sun-target-observer angles with the first 50 percent. Third, the randomization was operationally constrained by tactical sector; i.e., it was not possible to conduct all trial types in each tactical sector. (See table 1 for identification of the independent variables.)

Table 1. Independent variables (continued next page)

1. Ground observer search sector size.

   a. 60 degrees

   b. 120 degrees

2. Helicopter lateral maneuver (inverted "V").

   a. Maneuver

   b. No maneuver

3. Helicopter spacing.

   a. 250 meters

   b. <50 meters

   c. >500 meters

4. Helicopter pop-up position.

   a. Same position.

   b. Different from previous position (200 to 400 meter distance).

5. Range - helicopter-to-ground observer.

   a. 1,000 meters ± 10 percent.

   b. 2,000 meters ± 10 percent.

   c. 3,000 meters ± 10 percent.

   d. 5,000 meters ± 10 percent.

6. Helicopter background.

   a. Sky

   b. Terrain

Table 1. Independent variables (concluded)
7. Number and type of helicopter(s).
a. One OH-58 (equipped with canopy).
b. One OH-58 (without canopy).
c. One AH-1G (equipped with canopy).
d. One AH-1G (without canopy).
e. One OH-58 and one AH-1G (both equipped with canopy).
f. One OH-58 and one AH-1G (both without canopy).

2. BACKGROUND.

a. The objectives of the experiment were addressed by evaluating the performance of ground observers in the visual detection of single and multiple helicopters when employed in tactical situations. The helicopter tactics addressed in the experiment, and which were expected to have significant effects on the detectability of the helicopter(s), included lateral maneuver, helicopter spacing (AH-1G/OH-58 team only), time between pop-ups, pop-up position, range, background, number and type, and configuration; i.e., equipped with canopy or without canopy. Variation in ground observer tactics was limited to search sector size. One Scout helicopter (at 1, 2, 3, and 5 kilometer ranges), one attack helicopter (at 3 kilometer range), or one attack and one Scout helicopter (at 1, 2, and 3 kilometer ranges) were scheduled to pop up at predetermined positions from the ground observers. Pop-up tactics employed were relevant to expected tactical situations. The canopies were removed from one Scout and one attack helicopter to conduct a special series of comparison trials. This comparison was solely to determine the effect of canopy glint upon detection and not to determine the feasibility of operating a helicopter without a canopy. Ninety-six identical trials were conducted with canopies removed and with canopies installed in the helicopters. Throughout the experiment the attack helicopter was equipped with the blue tinted canopy.

b. The essential elements of analysis selected to address the objectives of this experiment are as follows:

EEA 1. What is the effect of canopy removal on the ground-to-air, visual detection of the AH-1G, OH-58, and AHT?

EEA 2. What is the effect of lateral maneuver (inverted V) on the ground-to-air visual detection of the AH-1G and OH-58?

EEA 3. What is the effect of lateral spacing between the AH-1G and OH-58, when presented simultaneously, on the ground-to-air visual detection of the AH-1G and OH-58?

EEA 4. What is the effect of observer search sector on the ground-to-air visual detection of the AH-1G, OH-58, and AHT?

EEA 5. What is the effect of helicopter background on the ground-to-air visual detection of the AH-1G, OH-58, and AHT?

EEA 6. What is the effect of position relocation between sequential pop-ups, for multiple pop-up events, on the ground-to-air visual detection of the OH-58 and AH-1G?

EEA 7. What is the effect between sequential pop-ups, for multiple pop-up events, on the ground-to-air visual detection of the OH-58 and AH-1G?

EEA 8. What is the effect of IR suppressant paint on the ground-to-air detection of the OH-58?

EEA 9. What is the effect of range on the OH-58 and the AHT?

c. The measures of effectiveness designated to answer the EEA are as follows:

(1) Median time to first detection (measured from start of line of sight).

(2) Median time to subsequent detection (measured from start of line of sight or from time of first detection).

(3) Proportion of true detections to detection opportunities.

(4) Frequency of reported detection cues.

3. EVALUATION OF CDEC REPORT.

a. The analysis performed by the Combat Development Experimentation Command (CDEC) on the data collected from Field Experiment 43.8, Phase IIA, consisted of performing analysis of variance (ANOVA) on the proportion of detections subsequent to an arcsine transformation of the data. Median times were computed for the overall measure of effectiveness (time to detect). Percentiles were computed, and observed cumulative distribution of times to detect were calculated and plotted.

b. Investigation into the distribution of the frequency of detections led to the finding that the data were not amenable to ANOVA. This finding was based on the lack of normality of the data in spite of the arcsine transformation. After the arcsine transformation was performed on the frequencies of detection, the Kolmogorov-Smirnov one-sample test was applied to the experimental data on canopy system, lateral maneuver, and range to determine which of the three distributions (normal, lognormal, exponential) best described the distribution of the transformed data. Under the null hypothesis that each data cell was normally distributed, with an $\alpha = 0.10$ level of significance, the following results were obtained.

(1) OH-58 Helicopter Canopy Experiment. Three of the eight cells were rejected under the null hypothesis. Three of the remaining five were found to be best described as lognormal.

(2) AH-1G Helicopter Canopy Experiment. Two of the eight cells were rejected. Three of the remaining six were found to be best described as lognormal.

(3) AH-1G and OH-58 Combination Canopy Experiment. Three of the eight cells were rejected. Two of the remaining five were best described as lognormal.

(4) OH-58 Helicopter Lateral Maneuver Experiment. Only one of the eight cells was rejected. Of the remaining cells two were best described as lognormal and one was best described as exponential.

(5) AH-1G Helicopter Lateral Maneuver Experiment. Two of the eight cells were rejected. Three of the remaining six were best described as lognormal.

(6) OH-58 Helicopter Range Experiment. Three of the twelve cells (four were not tested since they were previously tested in the canopy experiments) were rejected under the null hypothesis. Of the remaining nine, five were best described as lognormal and two as exponential.

c. The data also exhibited a high degree of inconsistency and dependence; i.e., in several trials only a small fraction of observers detected a good percentage of all targets, whereas the remaining observers detected no targets. When the assumptions of ANOVA are not met, the α-level of testing is not what it is specified to be. In this way the resultant presence or absence of significant factors and/or interactions is suspect. A case in point was the canopy experiment involving the AH-1G helicopter. In this experiment the factors were background, search sector, and canopy system. The experiment was conducted to determine the effect of search sector on the detectability of the helicopter at a range of 3,000 meters. The results of ANOVA run by CDEC concluded that search sector was not significant. The COA report evidenced otherwise. Within the terrain background trials, the AH-1G was observed with a significantly lower frequency within the 120° sector. (See figure 10, page 35.)

d. A large percentage of the times to detect were censored at 1 minute ($\pm$ 5 seconds), the constrained exposure time for each trial. Because the percentage of censored times was so large (greater than 50 percent in most cases), the calculated median times were close to 65 seconds. Little can be ascertained concerning the characterization of

the distributions for comparative analysis purposes. A conclusion of "....no observed difference existed between medians" has no statistical validity.

4. INCONGRUENT OBSERVATIONS.

a. Inconsistencies exist in the frequency of detection for the first pop-up for the multiple pop-up trials. All factors remained constant throughout all first pop-up trials for the OH-58 helicopter. Because of the identical factors, one would expect the frequencies of detection to be approximately the same; i.e., not significantly different. This was not the case. Obviously, other unknown factors entered into these trials. Due to the lack of insight into this experiment, a satisfactory explanation cannot be expounded at this time; however, incongruent behavior will be discussed in detail and in terms of the known factors.

b. Reference is made to table 2 for identification of trials for the initial pop-up (identified by factor-level combinations of the second pop-up) and the contingency tests performed on the frequency of detection for the first pop-up using the OH-58 helicopter. Because case III is significantly different from case IV at the $\alpha = 0.10$, cases I and II are also significantly different from case IV (because they are more extreme in proportion than III). Case II is significantly different from case III. These are the inconsistencies found within the 60^{o} search sector trials. Referring to table 3 for the 120^{o} search sector trials, it is evident that case I is significantly different from case III. (Cases II and IV are significantly different from case I.) Case II is significantly different from case III and case IV at the $\alpha = 0.10$ level of significance. Because of this inconsistent behavior in the data, these trials are suspect.

c. The trials conducted with the AH-1G helicopter contained similar inconsistencies. See tables 4 and 5 for the results of contingency tests performed on the frequencies of detection. Data from these trials were used in the OH-58 and AH-1G helicopter experiments involving the effects of canopy and lateral maneuver. Other trials resulted in inconsistent behavior of frequencies of detection; these trials will be surfaced in the course of the overall analysis. In order to "balance out" the unknown factors causing this erratic behavior, the frequencies were pooled within the 60^{o} and 120^{o} sectors for each of the helicopter experiments involving the multiple pop-up tactic. The assumption was that since these trials were conducted under identical conditions, an underlying distribution of frequency of detection should exist. By pooling these frequencies, the inconsistencies in the data would tend to be eliminated. This was considered

Table 2. OH-58 helicopter, 3,000 meter range, terrain background, 60^{o} search sector (continued next page)

	Detects	No Detects	Total
Case III	30	50	80
Case IV	13	67	80

H_0 (Null hypothesis): Cases III and IV represent equal proportions of detect to total opportunities for detection.

H_A (Alternate hypothesis): Cases III and IV do not represent equal proportions of detect to total opportunities for detection.

$$X^2 = 9.19, \quad \chi^2_{1df,\ 0.10} = 2.706$$

Since $X^2 > \chi^2$, reject H_0

I 38/79* Same position, 30 seconds elapsed time.**

II 46/80 Same position, 60 seconds elapsed time.

III 30/80 Different position, 30 seconds elapsed time.

IV 13/80 Different position, 60 seconds elapsed time.

* The frequency of detects divided by the total opportunities for detections on the first pop-up.

** The factor-level combinations under which the second pop-up trials were conducted.

Table 2. OH-58 helicopter, 3,000 meter range, terrain background, 60^{o} search sector (concluded)

	Detects	No Detects	Total
Case II	46	34	80
Case III	30	50	80

H_0 (Null hypothesis): Cases II and III represent equal proportions of detect to total opportunities for detection.

H_A (Alternate hypothesis): Cases II and III do not represent equal proportions of detect to total opportunities for detection.

$$X^2 = 6.42, \quad \chi^2_{1df,\ 0.10} = 2.706$$

Since $X^2 > \chi^2$, reject H_0.

I	38/79*	Same position, 30 seconds elapsed time.**
II	46/80	Same position, 60 seconds elapsed time.
III	30/80	Different position, 30 seconds elapsed time.
IV	13/80	Different position, 60 seconds elapsed time.

* The frequency of detects divided by the total opportunities for detections on the first pop-up.

** The factor-level combinations under which the second pop-up trials were conducted.

Table 3. OH-58 helicopter, 3,000 meter range, terrain background, 120^0 search sector (continued next page)

	Detects	No Detects	Total
Case I	9	71	80
Case III	21	59	80

H_0 (Null hypothesis): Cases I and III represent equal proportions of detect to total opportunities for detection.

H_A (Alternate hypothesis): Cases I and II do not represent equal proportions of detect to total opportunities for detection.

$$X^2 = 5.91, \quad \chi^2_{1df,\ 0.10} = 2.706$$

Since $X^2 > \chi^2$, reject H_0.

I 9/80 Same position, 30 seconds elapsed time.

II 33/79 Same position, 60 seconds elapsed time.

III 21/80 Different position, 30 seconds elapsed time.

IV 20/80 Different position, 60 seconds elapsed time.

Table 3. OH-58 helicopter, 3,000 meter range, terrain background, 120^{o} search sector (concluded)

	Detects	No Detects	Total
Case II	33	46	79
Case III	20	60	80

$X^2 = 5.03, \quad \chi^2_{1df,\ 0.10} = 2.706$

Since $X^2 > \chi^2$, reject H_0.

	Detects	No Detects	Total
Case II	33	46	79
Case IV	20	60	80

$X^2 = 5.03, \quad \chi^2_{1df,\ 0.10} = 2.706$

Since $X^2 > \chi^2$, reject H_0.

Table 4. AH-1G helicopter, 3,000 meter range, terrain background, 60^{0} search sector (continued next page)

	Detects	No Detects	Total
Case I	40	40	80
Case III	8	61	69

H_0 (Null hypothesis): Cases I and III represent equal proportions of detect to total opportunities for detection.

H_A (Alternate hypothesis): Cases I and III do not represent equal proportions of detect to total opportunities for detection.

$$X^2 = 25.02, \quad \chi^2_{1df,\ 0.10} = 2.706$$

Since $X^2 > \chi^2$, reject H_0.

I 40/80 Same position, 30 seconds elapsed time.

II 37/80 Same position, 60 seconds elapsed time.

III 8/69 Different position, 30 seconds elapsed time.

IV 9/77 Different position, 60 seconds elapsed time.

Table 4. AH-1G helicopter, 3,000 meter range, terrain background, 60^{0} search sector (concluded)

	Detect	No Detects	Total
Case I	40	40	80
Case IV	9	68	77

$X^2 = 26.82, \quad \chi^2_{1df,\ 0.10} = 2.701$

Since $X^2 > \chi^2$, reject H_0.

	Detects	No Detects	Total
Case II	37	43	80
Case IV	9	68	77

$X^2 = 22.60, \quad \chi^2_{1df,\ 0.10} = 2.701$

Since $X^2 > \chi^2$, reject H_0.

Table 5. AH-1G helicopter, 3,000 meter range, terrain background, 120^{0} search sector (continued next page)

	Detects	No Detects	Total
Case II	8	92	100
Case III	24	55	79

H_0 (Null hypothesis): Cases II and III represent equal proportions of detect to total opportunities for detection.

H_A (Alternate hypothesis): Cases II and III do not represent equal proportions of detect to total opportunities for detection.

$$X^2 = 15.05, \qquad \chi^2_{1df,\ 0.10} = 2.706$$

Since $X^2 > \chi^2$, reject H_0.

I 29/79 Same position, 30 seconds elapsed time.

II 8/100 Same position, 60 seconds elapsed time.

III 24/79 Different position, 30 seconds elapsed time.

IV 10/80 Different position, 60 seconds elapsed time.

Table 5. AH-1G helicopter, 3,000 meter range, terrain background, 120° search sector (concluded)

	Detects	No Detects	Total
Case III	24	55	79
Case IV	10	70	80

$X^2 = 7.56$, $\chi^2_{1df,\ 0.10} = 2.706$

Since $X^2 > \chi^2$, reject H_0.

	Detects	No Detects	Total
Case I	29	50	79
Case IV	10	70	80

$X^2 = 12.58$, $\chi^2_{1df,\ 0.10} = 2.706$

Since $X^2 > \chi^2$, reject H_0.

the best approach to obtain an estimate of the true frequency of detection for the respective conditions.

5. RESULTS OF ANALYSIS.

a. OH-58 Helicopter.

(1) Factor effects on the EEA.

(a) Factor conditions. The factor conditions under which the OH-58 was examined are presented as a design matrix in table 6. The first entry within each cell of this matrix is the frequency of detection. The second entry is the ratio of detections to total opportunities for detections. If the frequency of detection is greater than .50, the median time is also included (the third entry); otherwise, it is left blank.

(b) EEA 1 (Effect of canopy removal on the frequency of detection).

1. The effects of canopy removal upon ground-to-air detection frequency was examined at a 3-kilometer range with the OH-58 against terrain and sky backgrounds with the threat searching over 60° and 120° search sectors. It must be emphasized that this experiment was conducted to determine the effect of glint and not as an attempt to test the feasibility of operating an aircraft without a canopy.

2. Figure 1 graphically portrays the results of significance tests performed on the data in which the canopy was either present or absent.

3. The unexpected increase in frequency of detection when the canopy is removed in the 60° sky background trials rules out the possibility of a consistent conclusion with regard to the effect of canopy removal upon frequency of detection. This contradictory finding may have resulted from the presence or absence of some uncontrolled variable in the 60° sky trials.

(c) EEA 2 (Effect of lateral maneuver on the frequency of detection).

1. The effect of lateral maneuver was examined at a range of 3 kilometers with the OH-58 observed against a terrain and/or sky background and with the threat force observing over 60° and 120° search sectors. The OH-58 was configured with a canopy in all trials.

Table 6. Ground-to-air detection frequency and median time to detection for all factor-level combinations under which the OH-58 was examined

			Search Sector			
			60°		120°	
			Background		Background	
Range	Lateral Maneuver	Canopy	Sky	Terrain	Sky	Terrain
1 km	Without	With	.925 (37/40) 15.4	.475* (19/40)	.875 (35/40) 23.5	.225 (9/40)
2 km	Without	With	.555 (21/40) 53.1	.700 (28/40) 33.6	.220 (11/50)	.200 (6/30)
3 km	With	With	.696 (55/79) 37.1	.462 (37/80)	.712 (57/80) 32.3	.405 (32/79)
	Without	With	.086 (6/70)	.398 (127/319)	.212 (17/80)	.260 (83/319)
	Without	Without	.304 (21/69)	.400 (36/90)	.229 (16/70)	.122 (11/90)
5 km	Without	With	.139 (11/79)	.237 (19/80)	.247 (22/89)	.028 (2/70)

* The first entry in each cell is the detection frequency obtained under that cell's factor-level conditions. The entry in parentheses is (number of detections) ÷ (number of detection opportunities). When the frequency of detection is greater th an .50, the median time is shown as the third entry in the appropriate cells.

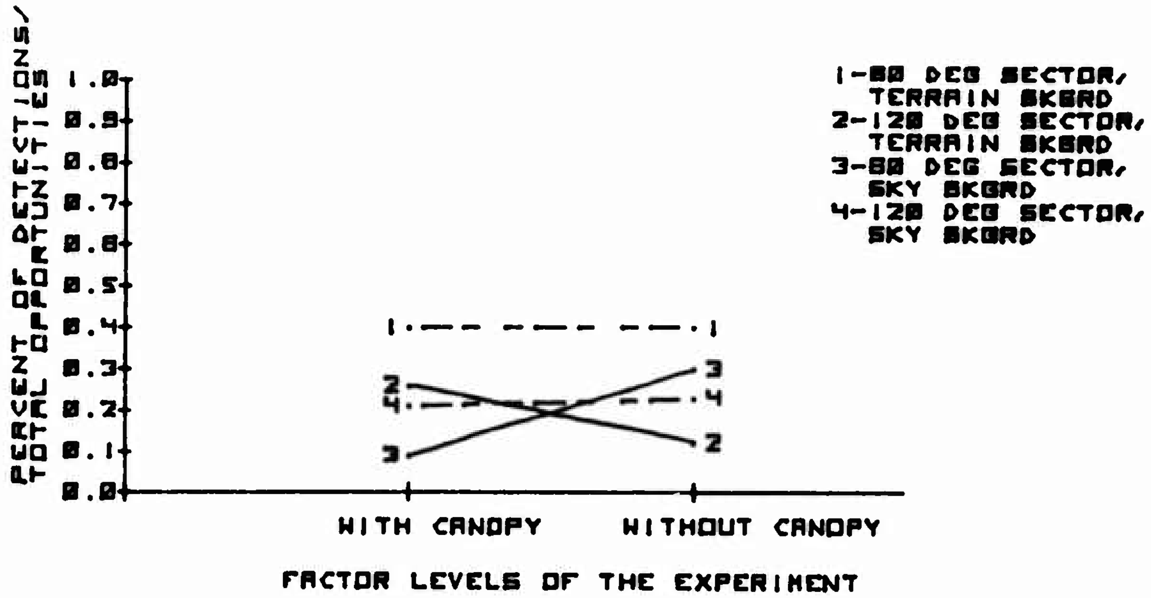


Figure 1. Effect of canopy removal on the frequency of detection of the OH-58 (solid lines denote significant differences; dashed lines denote nonsignificant differences)

2. The result of significance tests on data obtained when the OH-58 was, or was not, performing lateral maneuver is shown in figure 2.

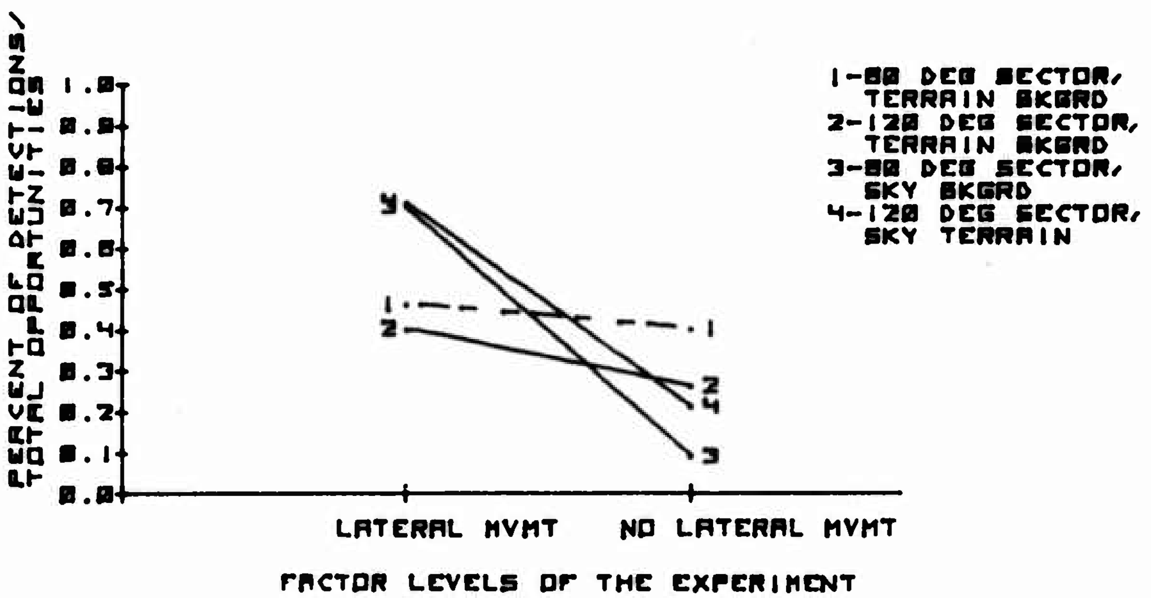


Figure 2. Effect of lateral maneuver on the frequency of detection of the OH-58 (solid lines denote significant differences; dashed lines denote nonsignificant differences)

3. The performance of lateral maneuver by the OH-58 caused a significant increase in the frequency with which it was detected in three of the four trial conditions. Additionally, note that the presence of lateral maneuver had a much more pronounced effect when the OH-58 was in a sky rather than a terrain background.

(d) EEA 4 (Effect of width of threat search sector upon frequency of detection).

1. The effect of width of ground search sector was examined under the following conditions:

a. 1, 2, 3, and 5 kilometers ranges.

(1) Canopy present.

(2) No lateral maneuver.

(3) Terrain and sky background.

b. 3 kilometer range.

(1) With canopy and lateral maneuver.

(2) Without canopy and no lateral maneuver.

(3) Terrain and sky background.

2. Results of significance tests are illustrated in figure 3.

3. Width of ground search sector had significant effects upon frequency of detection under 8 of 12 trial conditions. In six of the eight trials the ground forces' use of a 60^{o} search sector as opposed to a 120^{o} sector resulted in significant increases in OH-58 detection frequency. These increases varied from 160 percent to 846 percent.

4. At 3 and 5 kilometer ranges with the OH-58 in a sky background, the use of a 60^{o} search sector resulted in significantly smaller frequencies of detection. This apparent contradiction has no reasonable explanation.

5. One further point can be shown from this figure. Recalling that lateral maneuver apparently had a significant effect upon detection frequency, and now noting that width of search sector

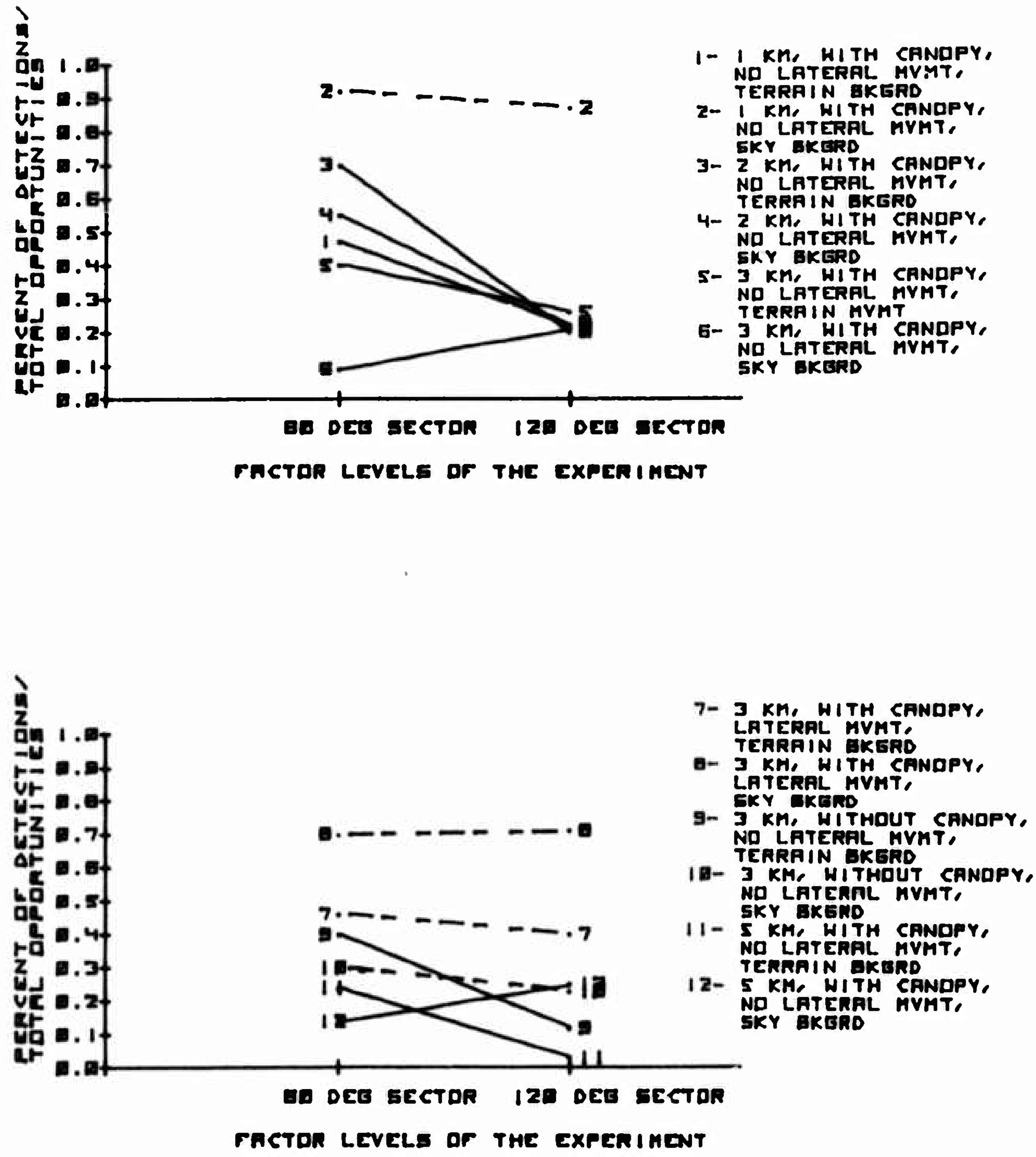


Figure 3. Effect of ground search sector upon frequency of detection of the OH-58 (solid lines denote significant differences; dashed lines denote nonsignificant differences)

also has a significant effect, note that when the OH-58 is performing lateral maneuver, width of search sector has no significant effect.

(e) EEA 5 (Effect of background upon the frequency of detection).

1. The effect of background was examined under the following conditions:

a. 1, 2, 3, and 5 kilometer ranges.

(1) Canopy present.

(2) No lateral maneuver.

(3) 60° and 120° search sector.

b. 3 kilometer range.

(1) With canopy and lateral maneuver.

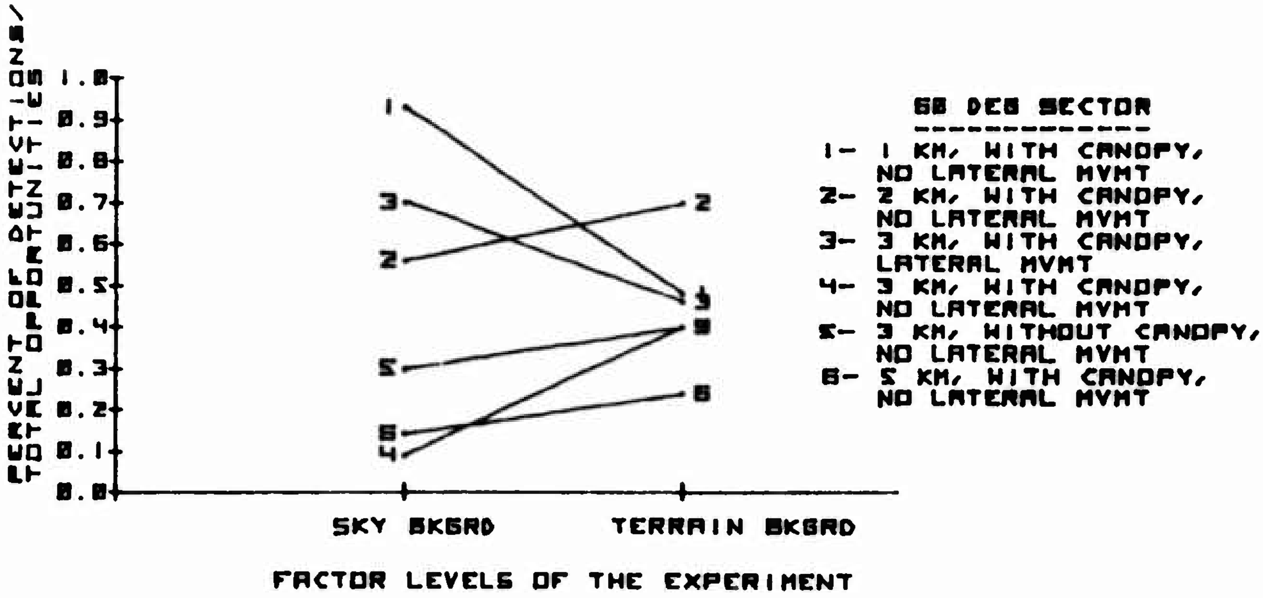
(2) Without canopy and no lateral maneuver.

(3) 60° and 120° search sector.

2. As a result of massive interactions of background and search sector, a slightly different format is used to present the results of significance tests related to the EEA. Figure 4 graphically illustrates the interactions and inconsistencies that occurred in these trials.

3. Under four of six trial conditions the ground force searching a 120° sector had a significantly higher frequency of detection when the OH-58 was against a sky rather than a terrain background. In the remaining two trial conditions background has no significant effect.

4. When the ground search sector narrows to 60°, however, an apparent interaction between search sector and background causes a significant reversal of effects, as evidenced by the fact that the presence of the OH-58 against a sky background results in a decreased detection frequency for four trial conditions ((2), (4), (5), and (6) in figure 4).



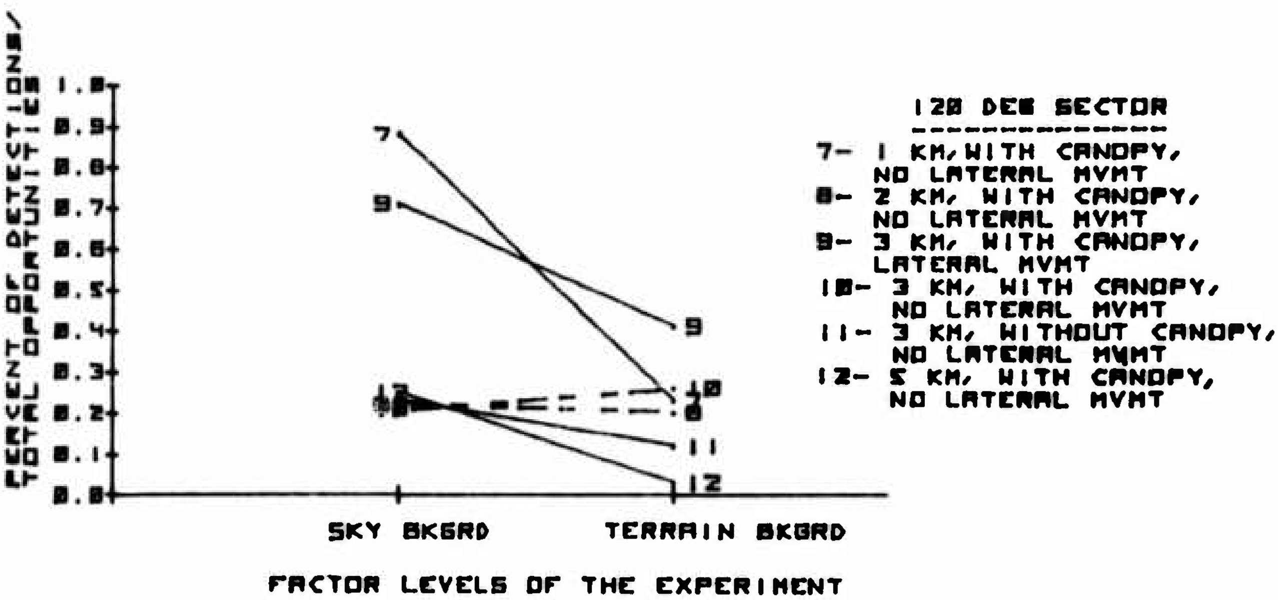


Figure 4. Effect of OH background upon the frequency of detection of the OH-58 (solid lines denote significant differences; dashed lines denote nonsignificant differences)

(f) EEA 6 and EEA 7 (Effect of position relocation and time elapsed between pop-ups on the frequency of detection of the OH-58 on its second pop-up).

1. The design matrix of the trials conducted to examine the effects of search sector, time elapsed between pop-ups, and second pop-up position on the frequency of detection for the OH-58 performing a second pop-up is shown in table 7. (The entries follow the same format as table 6.) All trials were conducted at a 3-kilometer range with a terrain background. See figure 5 for a graphic portrayal of factor effects.

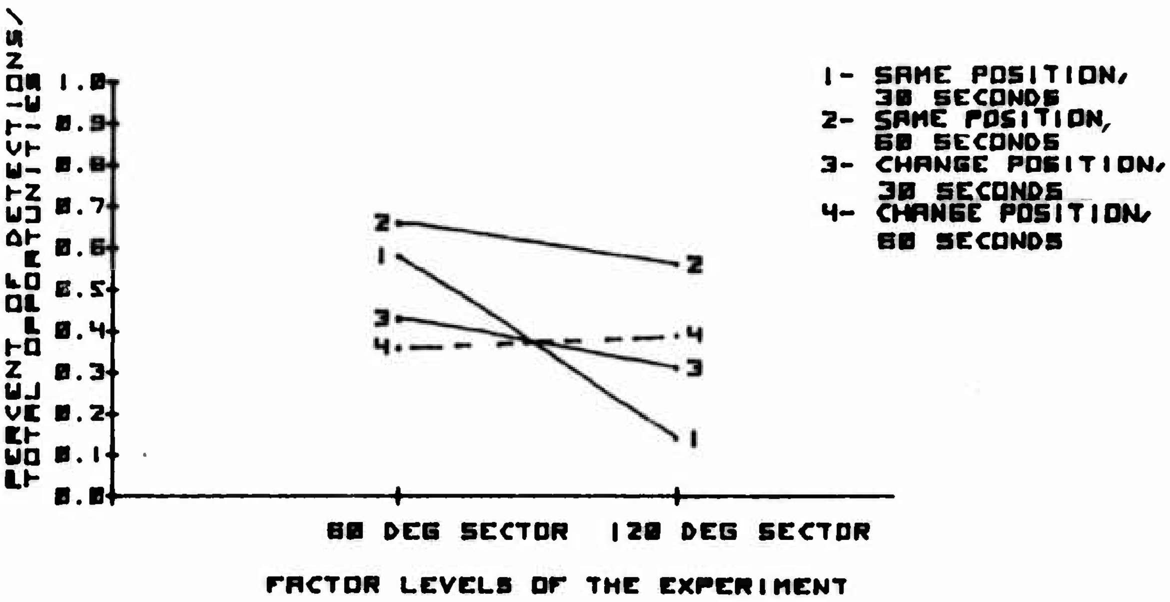
Table 7. Detection frequency and median time to detection of the OH-58 for the second pop-up trials

Position	Time between pop-ups			
	30 seconds		60 seconds	
	Search sector		Search sector	
	60^0	120^0	60^0	120^0
Same	.575 (46/80) 36.7	.137 (11/80)	.662 (53/80) 19.5	.557 (44/79) 34.3
Change	.425 (34/80)	.312 (25/80)	.355 (26/80)	.387 (31/80)

2. The 120^0 search sector produced significant decreases in frequency of detection on the second pop-up under all trial conditions except when the OH-58 changed positions with 60 seconds elapsed time between pop-ups.

3. The length of time between pop-ups produced no significant change in the frequency of detection on the second pop-up except when a 120^0 search was used and the same position was maintained.

4. Position change produced a significant decrease in the frequency of detection, except when the OH-58 remained masked for 30 seconds and the threat force was searching a 120^0 sector.



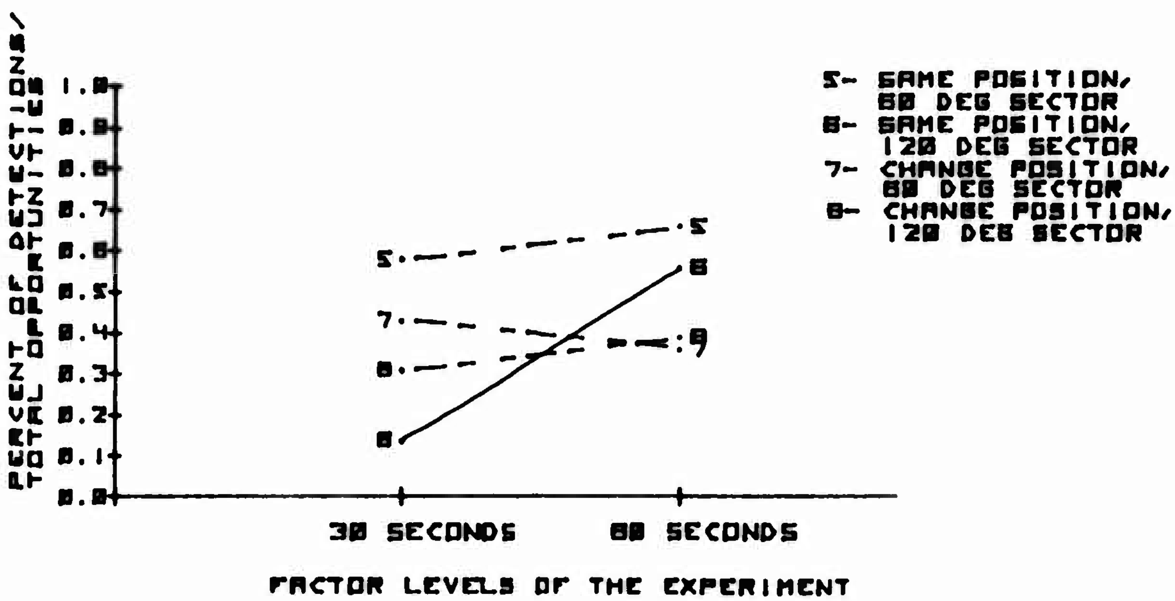


Figure 5. Effect of pop-up tactic upon frequency of detection of the OH-58 on its second pop-up (solid lines denote significant differences; dashed lines denote nonsignificant differences) (continued next page)

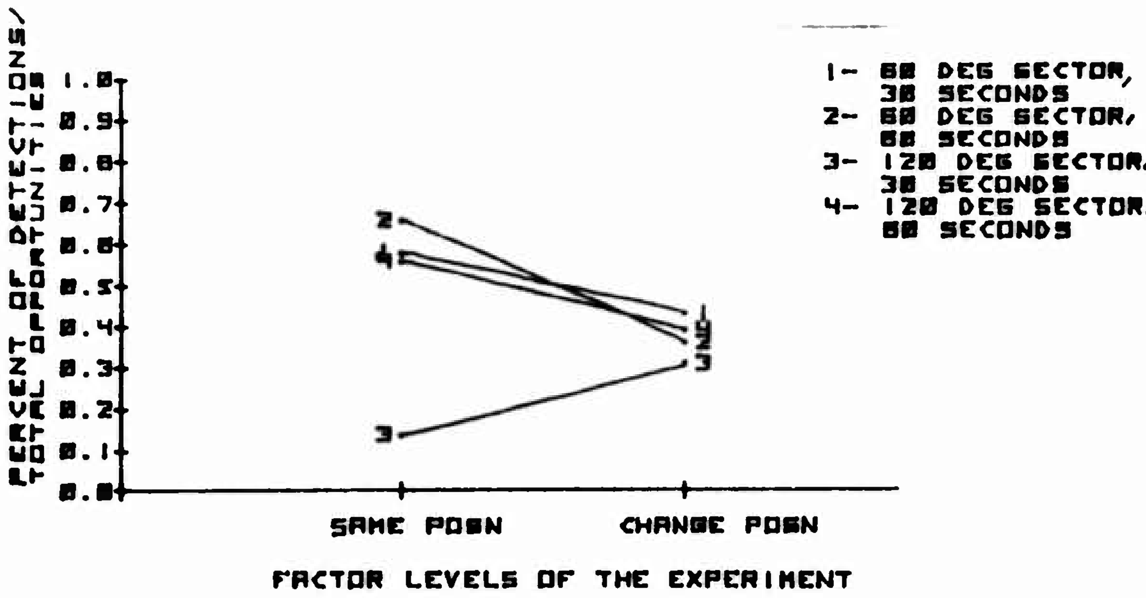


Figure 5. Effect of pop-up tactic upon frequency of detection of the OH-58 on its second pop-up (solid lines denote significant differences; dashed lines denote nonsignificant differences) (concluded)

(g) EEA 8 (Effect of IR suppressant paint upon the frequency of detection of the OH-58).

1. Identification of the detection data for the infrared (IR) suppressant paint experiment was not possible. CDEC selected at random a sample of 40 paired trials for examination.

2. The factors included in the experiment were background, search sector, and lateral maneuver. Table 8 depicts the 2 x 2 contingency matrix of the IR suppressant paint and the standard paint detection frequencies. It must be pointed out that these frequencies have been pooled over the factors search sector and lateral maneuver; the assumption was that they were not significant. The ground observers detected the OH-58 helicopter with a significantly lower frequency when the helicopter was coated with the IR paint. Figure 6 graphically portrays the effect of infrared suppressant paint on the frequency of detection. The color of the IR paint was black and it prevented the observer from visually detecting the helicopter due to metal glint. It is not known whether any other color IR paint would produce similar results.

Table 8. Frequency of detection for the infrared suppressant paint trials

		Background			
		Sky		Terrain	
		Detect	No detect	Detect	No detect
Paint	Infrared	55	55	81	209
	Standard	68	42	122	158

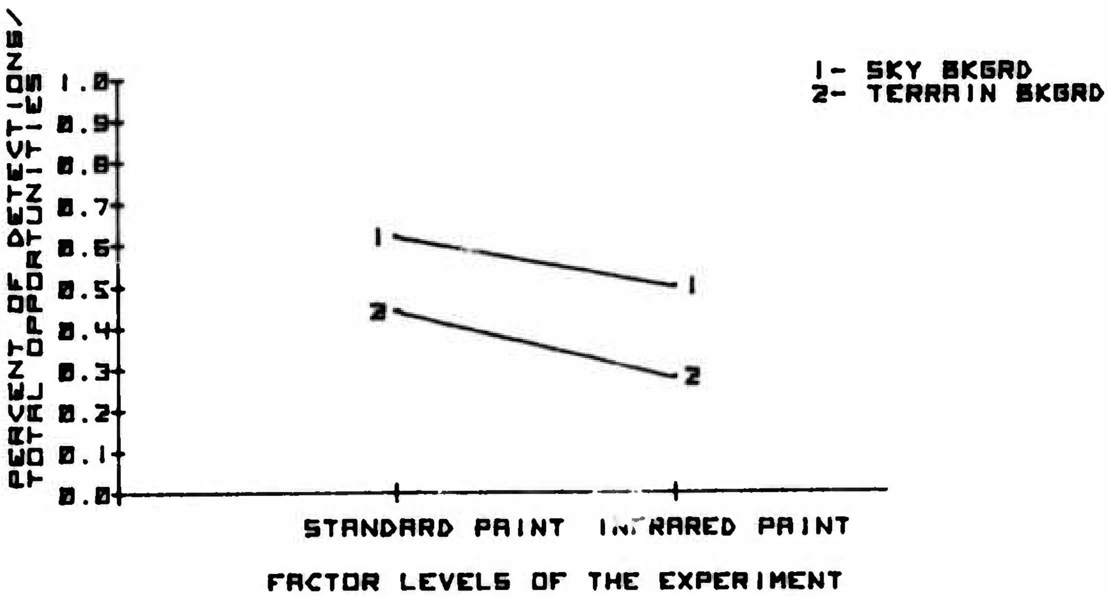


Figure 6. Effect of infrared paint upon the frequency of detection (solid lines denote significant differences)

(h) EEA 9 (Effect of detection range upon the frequency of detection).

1. The effect of detection range was examined under the following conditions:

(a) 60° and 120° search sector.

(b) Terrain and sky background.

(c) With canopy (all ranges).

(d) Without canopy (3 kilometers only).

(e) No lateral maneuver (all ranges).

(f) With lateral maneuver (3 kilometers only).

2. Results of significance tests for the effects of range upon frequency of detection are given in figure 7.

3. An increase in range between the ground force and the OH-58 resulted in a significantly decreased frequency of detection under six of the 12 trial conditions and had no effect under five trial conditions. The increase in detection frequency when the OH-58 moved from 1 to 2 kilometers in a 60° sector with terrain background is unexplainable.

(2) Summary of factor effects on EEA.

(a) EEA 1. The results on canopy effects were inconclusive.

(b) EEA 2. Lateral maneuver increased the detectability of the OH-58.

(c) EEA 4. Irrespective of pop-up, the 120° search sector generally decreased the frequency of detection.

(d) EEA 5. The results on background effects were inconclusive.

(e) EEA 6. Position relocation generally decreased the detectability of the OH-58.

(f) EEA 7. In general, the time elapsed between pop-up was insignificant.

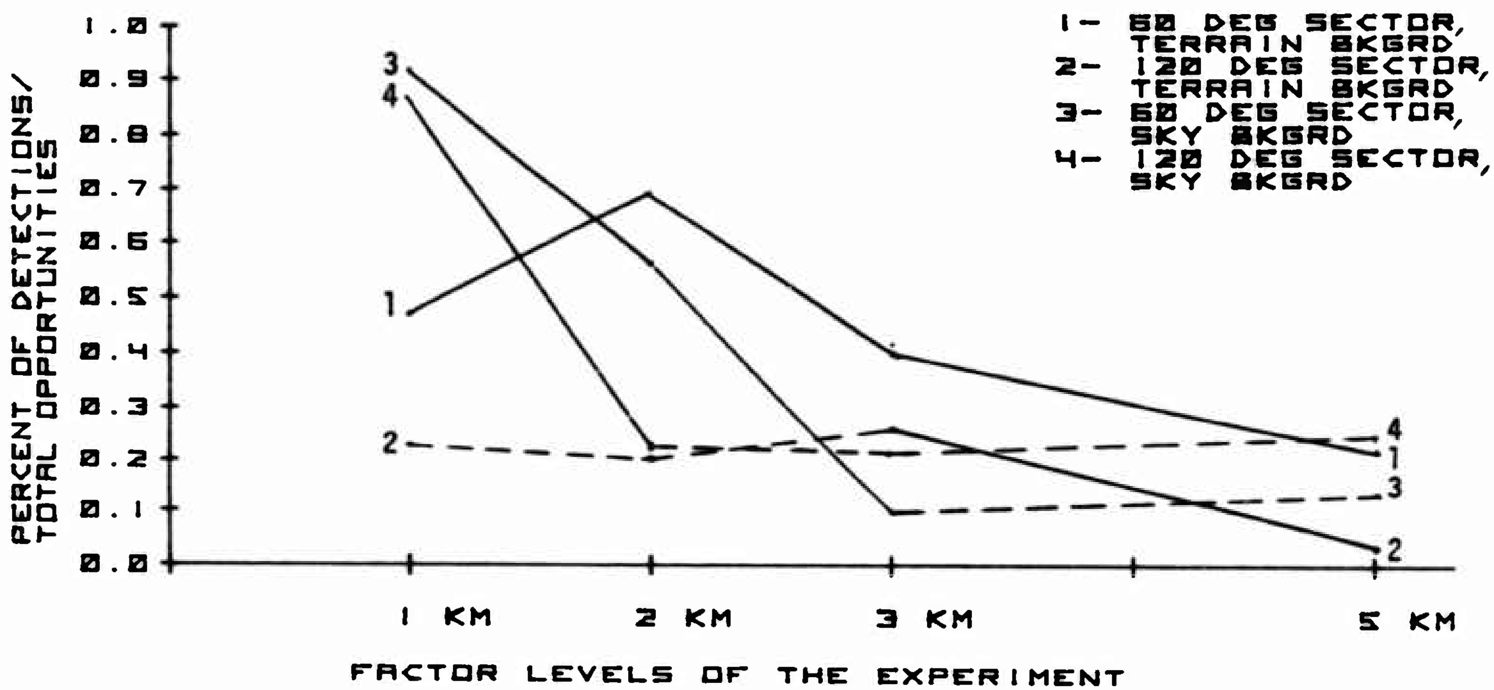


Figure 7. Effect of detection range upon the frequency of detection of the OH-58 (solid lines denote significant differences; dashed lines denote non-significant differences)

(g) EEA 9. An increase in range generally had no effect on the frequency of detection within the 120° search sector. Within the 60° search sector, an increase in range decreased the detectability of the OH-58.

(3) Evaluation of OH-58 tactics.

(a) Single pop-up tactic.

1. The OH-58 with canopy was allowed to use the following tactics during the field experiment: I - no lateral maneuver with a terrain background, II - lateral maneuver with a terrain background, III - no lateral maneuver with a sky background, and IV - lateral maneuver with a sky background.

2. At ranges of 1, 2, and 5 kilometers only OH-58 tactics I and III were examined. At 3 kilometers, all four tactics were allowed.

3. Application of the minimax criterion is summarized in table 9. (See appendix B for a discussion of decision theory.) The following conclusions can be drawn with regard to the tactic to be used by the OH-58 to minimize his expected frequency of detection.

(a) At a range of 1 kilometer the OH-58 should use tactic I (no lateral maneuver and maintain a terrain background) regardless of the search sector used by the ground force.

(b) At ranges of 2 and 3 kilometers the OH-58 should use tactic III (no lateral maneuver and maintain a sky background) regardless of the search sector used by the ground force.

(c) At a 5-kilometer range the OH-58 should use tactic I (no lateral maneuver and maintain a terrain background) regardless of the search sector used by the ground force.

(b) Multiple pop-up tactic.

1. Table 10 depicts the minimax matrix of detection frequency for the OH-58 within the canopy trials. Four distinct tactics were present: I - same position with 30 seconds elapsed, II - same position with 60 seconds elapsed, III - change position with 30 seconds elapsed, and IV - change position with 60 seconds elapsed.

Table 9. Minimax decision matrix of the frequency of detection for the OH-58 single pop-up tactic

Range	OH-58 Tactic	Lateral Maneuver	Background	Threat Search Sector		OH-58 Minimax Tactic	Threat Maximin Tactic
				60°	120°		
1 km	I	Without	Terrain	.475	.225	I	60°
	III	Without	Sky	.925	.875		
2 km	I	Without	Terrain	.700	.200	III	60°
	III	Without	Sky	.555	.220		
3 km	I	Without	Terrain	.398	.260	III	120°
	II	With	Terrain	.462	.405		
	III	Without	Sky	.086	.212		
	IV	With	Sky	.696	.712		
5 km	I	Without	Terrain	.237	.028	I*	60°
	III	Without	Sky	.139	.247		

* There is no significant difference between the frequencies .237 and .247.

Table 10. The minimax decision matrix of the detection frequency for the OH-58 multiple pop-up tactics

		Position	Elapsed time	Threat search sector: 60°	120°	Max
OH-58 tactics	I	Same	30 sec	57.5	13.7	57.5
	II	Same	60 sec	66.2	55.7	66.2
	III	Change	30 sec	42.5	31.2	42.5
	IV	Change	60 sec	35.5	38.7	38.7
			Min	35.5	13.7	

2. Tactic IV is determined to be the most favorable tactic for the friendly force.

3. The threat force, with an identical intelligence capability, will employ the 60° search sector. This will permit the threat force to increase its detection frequency in three of four tactical postures the friendly forces can employ.

b. AH-1G Helicopter, 3,000 Meter Range.

(1) Factor effects on the EEA.

(a) Factors. The design matrix for the AH-1G trials conducted to examine the effects of canopy system, lateral maneuver, background, and search sector on the frequency of detection is shown in table 11. These trials consisted of a single pop-up with a maximum exposure time of 65 seconds. The first entry within each cell is the frequency of detection. The ratio in parentheses is the number of

detections made by 10 observers divided by the total opportunities for detection. If the frequency of detection is greater than .500, the median time required for detection is also included (the third entry); otherwise, it is left blank.

Table 11. Ground-to-air detection frequency and median time to detection for the AH-1G

			Search Sector			
			60°		120°	
			Background		Background	
Range	Lateral Maneuver	Canopy	Sky	Terrain	Sky	Terrain
3 km	With	With	.780 (78/100) 21.9	.607 (48/79) 32.7	.739 (52/69) 26.8	.400 (32/80)
	Without	With	.386 (27/70)	.307 (94/304)	.627 (37/59) 21.0	.210 (71/338)
		Without	.378 (34/90)	.286 (20/70)	.303 (27/89)	.186 (13/70)

(b) EEA 1 (Effect of canopy removal on the frequency of detection).

1. Canopy system was not significant within the terrain background trials.

2. Only within the 120° search sector did the absence of canopy significantly decrease the frequency of detection for the AH-1G against a sky background.

3. The effect of canopy on the frequency of detection is graphically portrayed in figure 8.

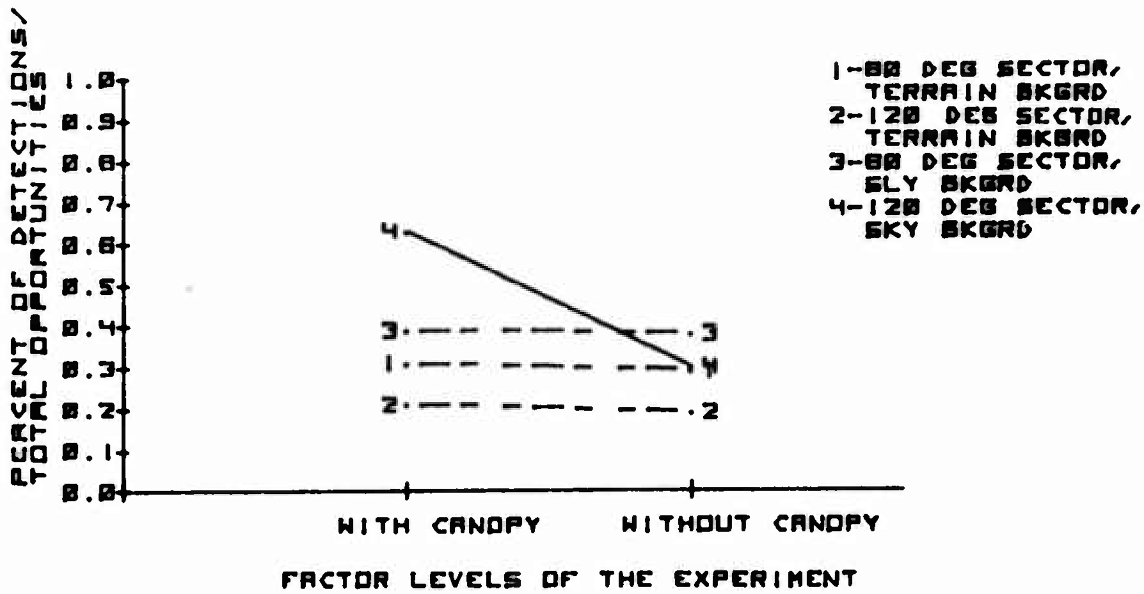


Figure 8. The effect of canopy on the frequency of detection for the AH-1G (solid lines denote significant differences; dashed lines denote nonsignificant differences)

(c) EEA 2 (Effect of lateral maneuver on the frequency of detection). Irrespective of background, the AH-1G significantly decreased its detection frequency when not performing lateral maneuver. (See figure 9.)

(d) EEA 4 (Effect of threat search sector on the frequency of detection). Paragraph 1 below represents an interaction of search sector and background. Figure 10 graphically portrays the results of significance tests for this EEA.

1. With canopy and without lateral maneuver.

a. Against a terrain background the 120^{0} search sector significantly decreased the frequency of detection for the AH-1G.

b. Against a sky background the 60^{0} search sector significantly decreased the frequency of detection. This apparent inconsistency is not readily explainable other than by extraneous factor(s) possibly influencing this outcome.

2. Without canopy and without lateral maneuver.

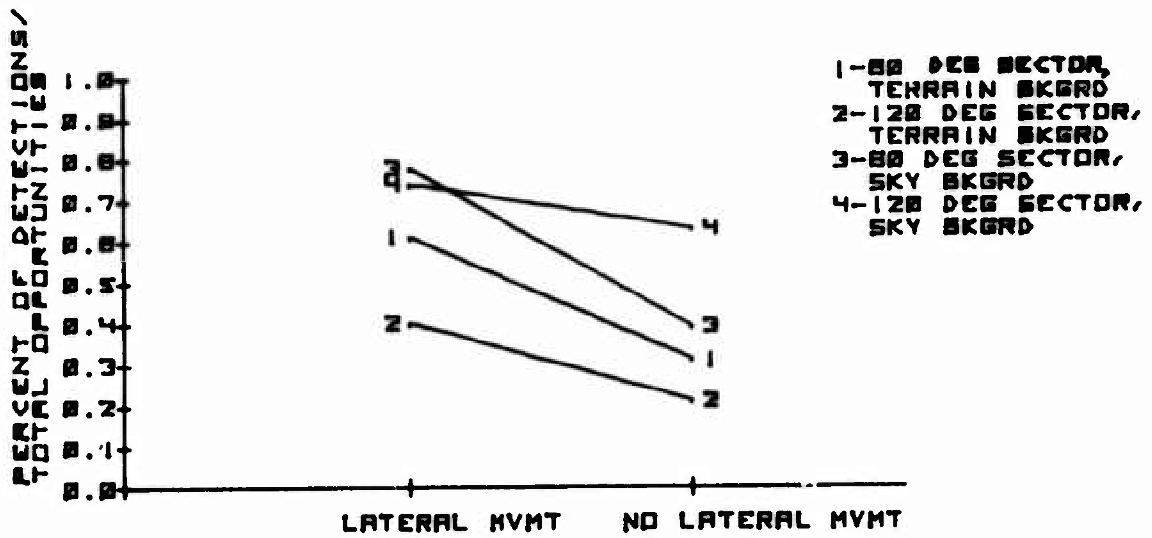


Figure 9. The effect of lateral maneuver on the frequency of detection for the AH-1G (solid lines denote significant differences)

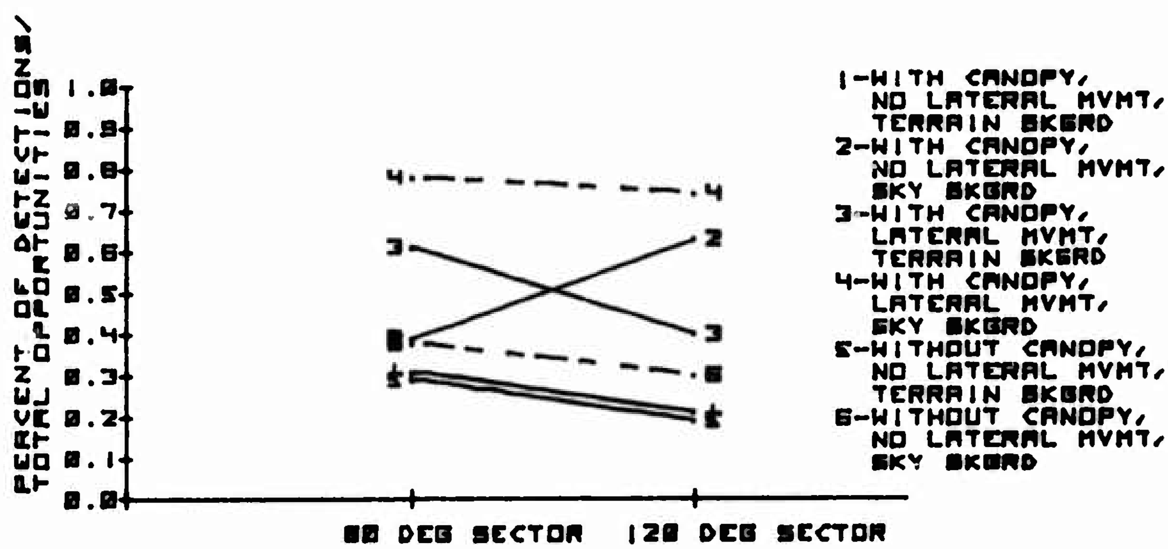


Figure 10. The effect of search sector on the frequency of detection for the AH-1G (solid lines denote significant differences; dashed lines denote nonsignificant differences)

a. Against a terrain background the 120° search sector decreased the frequency of detection.

b. Against a sky background search sector was not significant.

3. With canopy and with lateral maneuver.

a. Against a terrain background the 120° search sector significantly decreased the frequency of detection for the AH-1G.

b. Search sector was not significant within the sky background trials.

(e) EEA 5 (Effect of background on the frequency of detection). Paragraphs 1 and 2 below each represent an interaction of search sector and background. (See figure 11.)

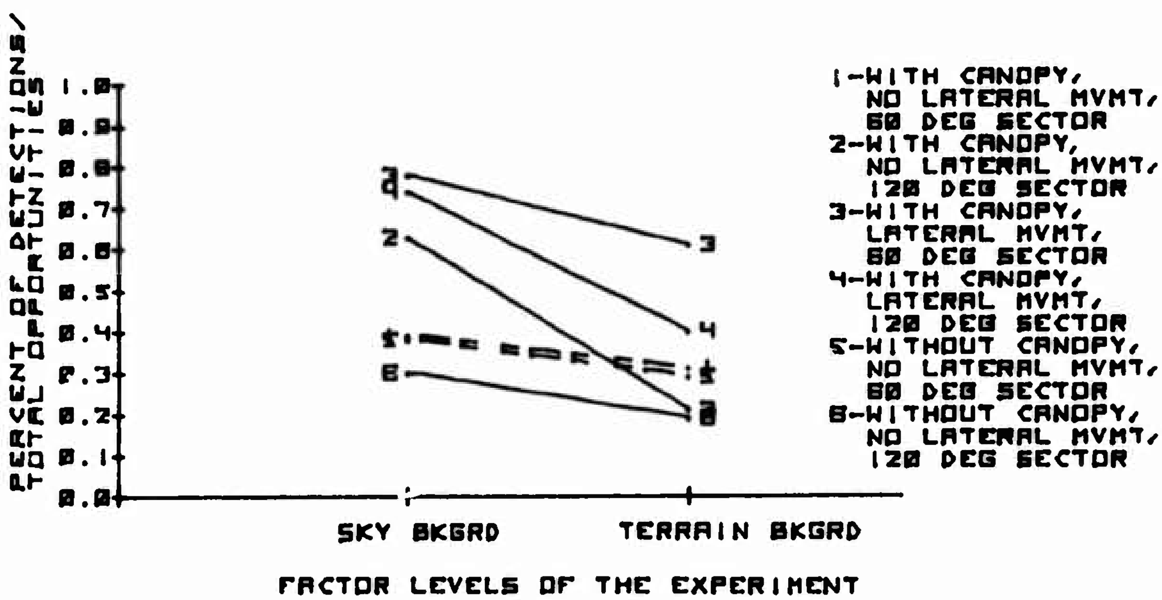


Figure 11. The effect of background on the frequency of detection for the AH-1G (solid lines denote significant differences; dashed lines denote nonsignificant differences)

1. With canopy and without lateral maneuver.

a. Terrain background significantly decreased the frequency of detection for the AH-1G within a 120° search sector.

b. Background was not a significant factor within the 60° search sector.

2. Without canopy and without lateral maneuver.

a. Terrain background significantly decreased the frequency of detection for the AH-1G within the 120° search sector.

b. Background was not a significant factor within the 60° search sector.

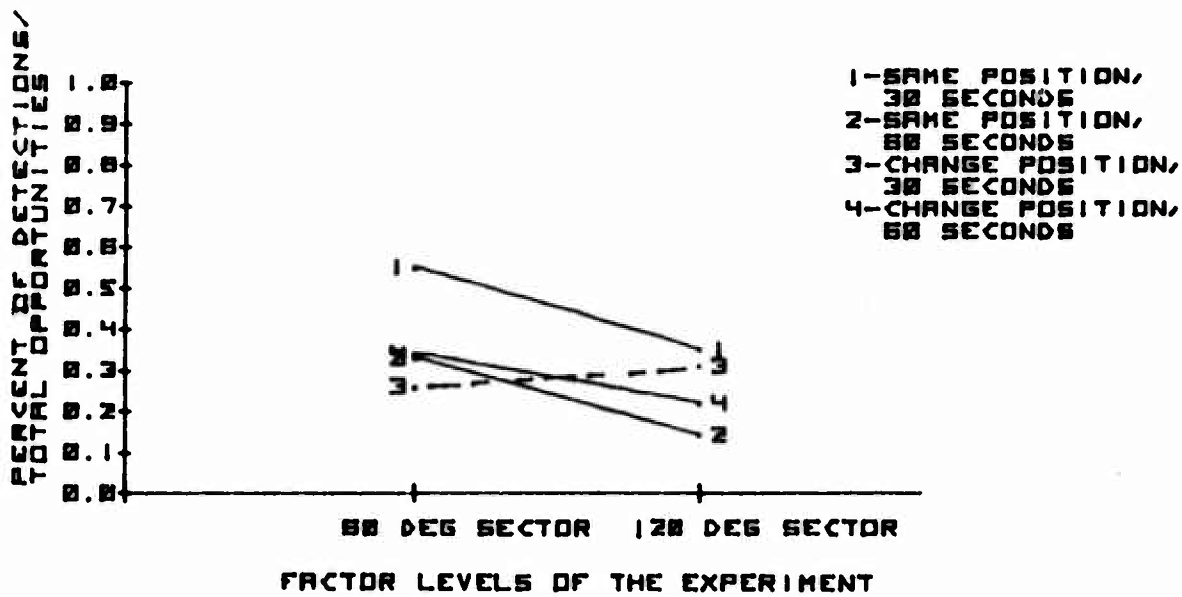
3. With canopy and with lateral maneuver. Terrain background significantly decreased the frequency of detection for the AH-1G, irrespective of search sector.

(f) EEA 6 and EEA 7 (Effect of position relocation and time elapsed between pop-ups on the frequency of detection for the AH-1G on its second pop-up).

1. The design matrix of the trials conducted to examine the effects of search sector, time elapsed between pop-ups, and second pop-up position on the frequency of detection for the AH-1G performing a second pop-up is shown in table 12 (the entries follow the same format as table 1). All trials were conducted against a terrain background. See figure 12 for a graphic portrayal of factor effects.

Table 12. Detection frequency and median time to detection of the AH-1G for the second pop-up trials

Position	Time between pop-ups			
	30 seconds		60 seconds	
	Search sector		Search sector	
	60°	120°	60°	120°
Same	.550 (44/80) 38.1	.350 (28/80)	.325 (26/80)	.140 (14/100)
Changed	.257 (18/70)	.312 (25/80)	.337 (27/80)	.215 (17/79)



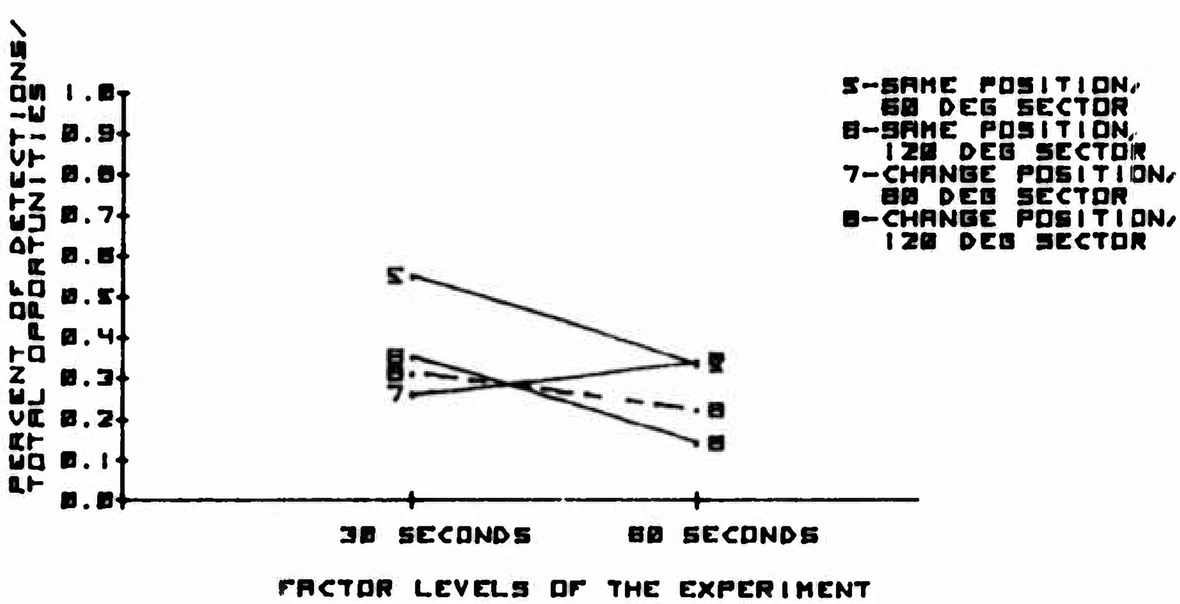


Figure 12. Effect of pop-up tactics on the frequency of detection for the AH-1G unit's second pop-up (solid lines denote significant differences; dashed lines denote nonsignificant differences (continued next page)

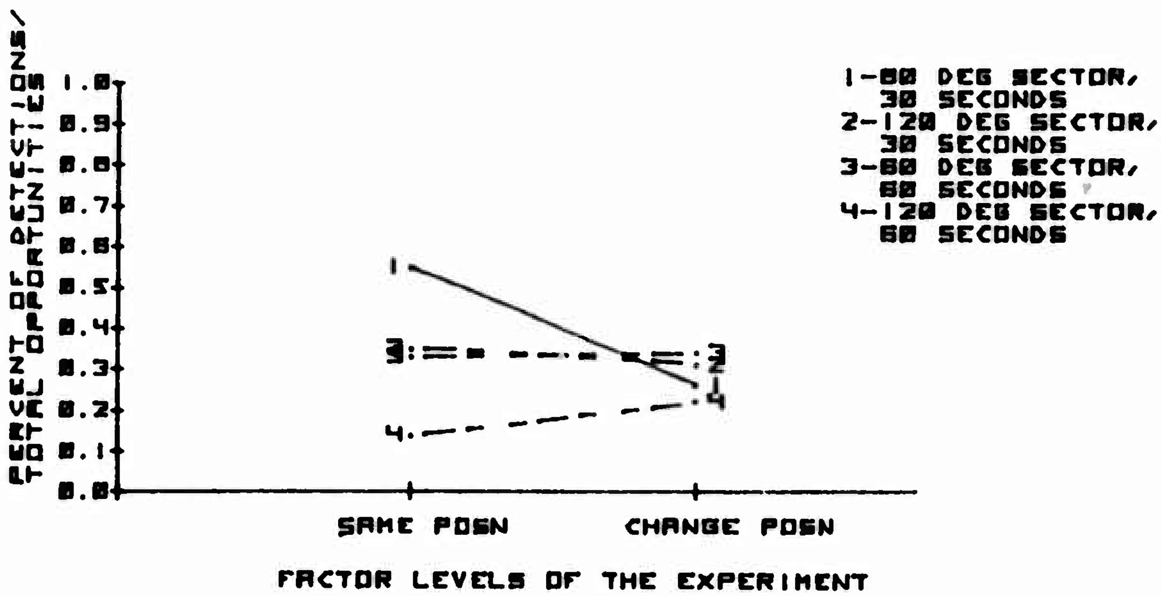


Figure 12. Effect of pop-up tactics on the frequency of detection for the AH-1G unit's second pop-up (solid lines denote significant differences; dashed lines denote nonsignificant differences (concluded)

2. The 120^0 search sector produced significant decreases in the frequency of detection on the second pop-up for all trials except when the AH-1G popped up in a different position with 30 seconds elapsed between pop-ups.

3. Position change was not significant for all trials except when the helicopter remained masked for 30 seconds and the threat force was searching a 60^0 search sector.

4. The 60 seconds elapsed time between pop-ups significantly decreased the frequency of detection for all trials except for the change position trials with the threat force searching a 60^0 search sector.

(2) Summary of factor effects on EEA.

(a) EEA 1. In general, canopy system did not have an effect on the frequency of detection for the AH-1G.

(b) EEA 2. Lateral maneuver increased the detectability of the AH-1G.

(c) EEA 4. Irrespective of pop-up, the 120^0 search sector generally decreased the frequency of detection.

(d) EEA 5. The detectability of the AH-1G was decreased against a terrain background.

(e) EEA 6. In general, position relocation did not have an effect on detectability.

(f) EEA 7. The 60 seconds elapsed time between pop-ups generally decreased the frequency of detection for the AH-1G.

(3) Evaluation of AH-1G tactics.

(a) Single pop-up tactics.

1. Table 13 depicts the minimax matrix of frequencies of detection for the AH-1G. Within the canopy trials, four distinct tactics were present: I - no lateral maneuver with terrain background, II - no lateral maneuver with sky background, III - lateral maneuver with terrain background, and IV - lateral maneuver with sky background. The optimum frequency for both the friendly and threat forces is 30.7.

Table 13. Minimax decision matrix of the detection frequency for the AH-1G single pop-up tactic

				Threat Search Sector		
		Lateral Maneuver	Background	60°	120°	Max
AH-1G tactics	I	Without	Terrain	30.7	21.0	30.7
	II	Without	Sky	38.6	62.7	62.7
	III	With	Terrain	60.7	40.0	60.7
	IV	With	Sky	78.0	73.9	78.0
			Min	30.7	21.0	

2. The table demonstrates that the friendly force should employ tactic I, regardless of the threat forces sector of search. This tactic will minimize the maximum frequencies of detections (i.e., the "best" of all "worst" cases).

3. On the other hand, the threat forces with an identical intelligence capability, will employ the 60^{0} search sector as a means of maximizing the minimum frequencies of detection. Employing the 60^{0} sector enables the threat forces to obtain a greater probability of detection when compared to the 120^{0} sector.

(b) Multiple pop-up tactics.

1. In the multiple pop-up experiment for the AH-1G the four tactics are depicted in table 14 as I - same position with 30 seconds elapsed, II - same position with 60 seconds elapsed, III - change position with 30 seconds elapsed, IV - change position with 60 seconds elapsed.

Table 14. The minimax decision matrix for AH-1G, multiple pop-up tactics

				Threat Search Sector		
		Position	Elapsed time	60^{0}	120^{0}	Max
AH-1G tactics	I	Same	30 sec	55.0	35.0	55.0
	II	Same	60 sec	32.5	14.0	32.5
	III	Change	30 sec	25.7	31.2	31.2
	IV	Change	60 sec	33.7	21.5	33.7
			Min	25.7	14.0	

2. Tactic III is determined to be the most favorable tactic for the friendly force.

3. The threat force, with an identical intelligence capability, will employ the 60^{o} search sector. This decision will permit the threat force to increase its detection frequency in three of the four tactical postures the friendly forces can employ. In addition, if the threat force did not possess the same intelligence information, they would more than likely employ the 60^{o} as the logical sector for the greater frequency of detection.

c. AHT. One AH-1G and One OH-58.

(1) Results on EEA. The design matrices for AHT trials where at least one helicopter of the team was detected and both helicopters were detected are shown at tables 15 and 16, respectively. Independent variables of the experiment were search sector, range, background, lateral spacing between helicopters, and the presence or absence of canopies on the AHT. The design was fully factorial with the exception that lateral spacing was considered a variable only at 3,000 meters range and canopy was considered a variable only for lateral spacing greater than 500 meters. The first two entries in the tables are the frequency of detection and the ratio of successful to attempted detections on which the frequency is based. If the first entry exceeds .500, the median time to detect was less than 65 seconds and appears as the third entry in the cell. The median time is greater than 65 seconds where no third entry appears.

(a) EEA 1 (Effect of canopy removal on frequency of detection). The frequencies of detection for this element of analysis are shown in tables 15 and 16. The tables represent experiment outcomes at 3,000 meters range with lateral spacing of helicopters greater than 500 meters.

1. 60^{o} search sector.

a. Against sky background the presence of canopies decreased the frequency of detection of the AHT.

b. Against terrain background the absence of canopies decreased the frequency of detection.

2. 120^{o} search sector. The presence or absence of canopies had no significant effect on frequency of detection regardless of background.

Table 15. Ground-to-air detection frequency and median time to detection when at least one AHT team member was detected

Range	Lateral Spacing (meters)	Canopy	Search Sector: 60^{o}, Background: Sky	Search Sector: 60^{o}, Background: Terrain	Search Sector: 120^{o}, Background: Sky	Search Sector: 120^{o}, Background: Terrain
1 km	250	With	.980 (49/50) 26.9	.767 (23/30) 36.4	.975 (39/40) 22.9	.925 (37/40) 23.9
2 km	250	With	.900 (27/30) 28.6	.680 (34/50) 35.7	.950 (38/40) 30.5	.375 (15/40)
3 km	<50	With	.800 (56/70) 35.9	.511 (46/90) 61.0	.406 (28/69)	.506 (40/79)
	>500	With	.717 (43/60) 35.2	.409 (45/110)	.438 (35/80)	.289 (26/90)
		Without	.833 (50/60) 38.4	.088 (7/80)	.350 (28/80)	.367 (22/60)

Table 16. Ground-to-air detection frequency and median time to detection of both AHT team members

Range	Lateral Spacing (meters)	Canopy	Search Sector 60° Background Sky	Search Sector 60° Background Terrain	Search Sector 120° Background Sky	Search Sector 120° Background Terrain
3 km	<50	With	.543 (38/70) 48.1	.211 (19/90)	.116 (8/69)	.253 (20/79)
	>500	Without	.100 (6/60)	.009 (1/110)	.013 (1/80)	.011 (1/90)

3. The quantitative effect of canopies on frequency of detection is portrayed graphically in figure 13. Against sky background the increased frequency of detection cannot be explained except to say that unidentified factors may have influenced experiment outcomes. Results against terrain background are reasonable since canopy "glint" was a frequently reported detection cue. It would also be expected that canopies have the potential of increasing color contrast against terrain background.

(b) EEA 3 (Effect of AHT lateral spacing on frequency of detection). Results of this element of analysis are based on an AHT equipped with canopies at 3,000 meters range. Frequencies of detection used for analysis are shown in table 15 (at least one helicopter detected) and table 16 (both helicopters detected).

1. Terrain background. Against terrain background the frequency of detection decreased for lateral spacing greater than 500 meters regardless of search sector.

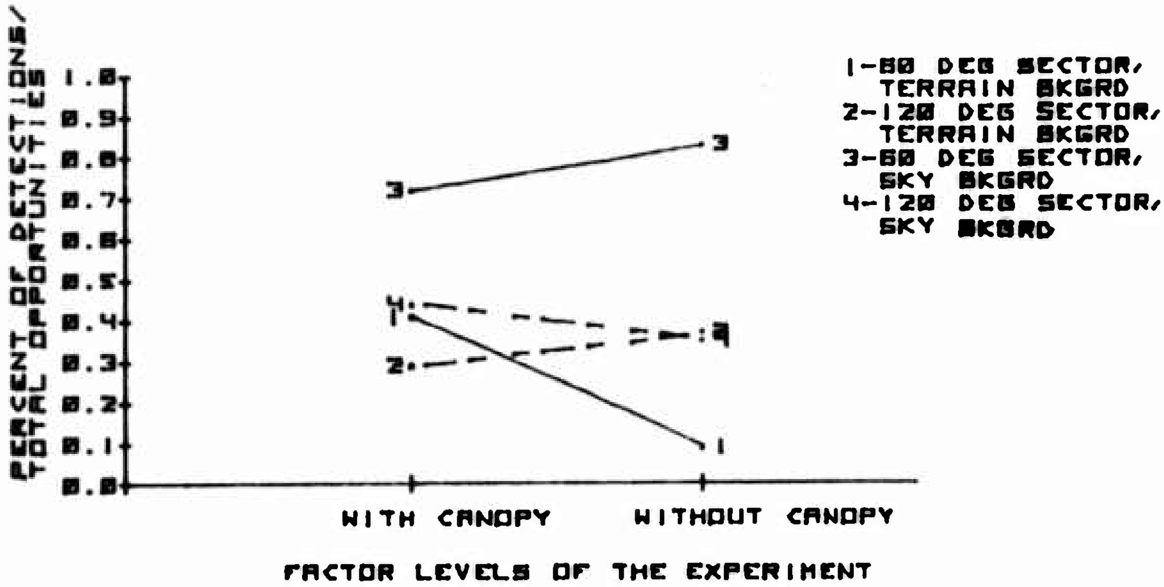


Figure 13. Effect of canopy on frequency of detection of at least one member of the AHT (solid lines denote significant differences; dashed lines denote nonsignificant differences)

2. Sky background. Lateral spacing had no significant effect for an AHT presented against sky background.

3. Both helicopters detected. Lateral spacing greater than 500 meters decreased frequency of detection in all cases when both helicopters of the AHT were detected. This was true regardless of the factors search sector and background.

4. Lateral spacing. The effect of lateral spacing is shown graphically in figures 14 and 15. Frequency of detection was consistently lower when the AHT employed wide lateral spacing. With lateral spacing less than 50 meters at 3,000 meters range the AHT might appear as one larger mass (specular fusion) and therefore be more easily detected. It should be noted from figure 15 that close spacing caused substantial increases in frequency of detection of both helicopters. When the ground observer saw one helicopter the remaining helicopter was only a few degrees of arc to the right or left and was often detected.

(c) EEA 4 (Effect of threat search sector on frequency of detection). The data for this analysis are those of table 15 (at least one helicopter detected) and table 16 (both helicopters detected). Trials run without canopies are not considered.

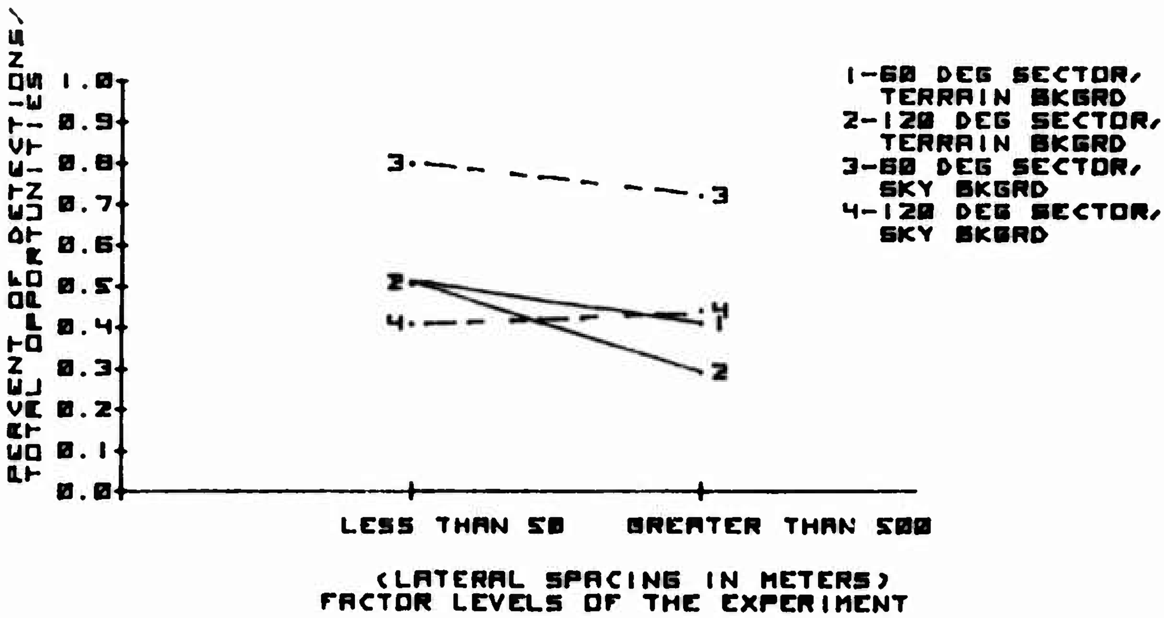


Figure 14. Effect of AHT lateral spacing on frequency of detection for at least one helicopter (solid lines denote significant differences; dashed lines denote nonsignificant differences)

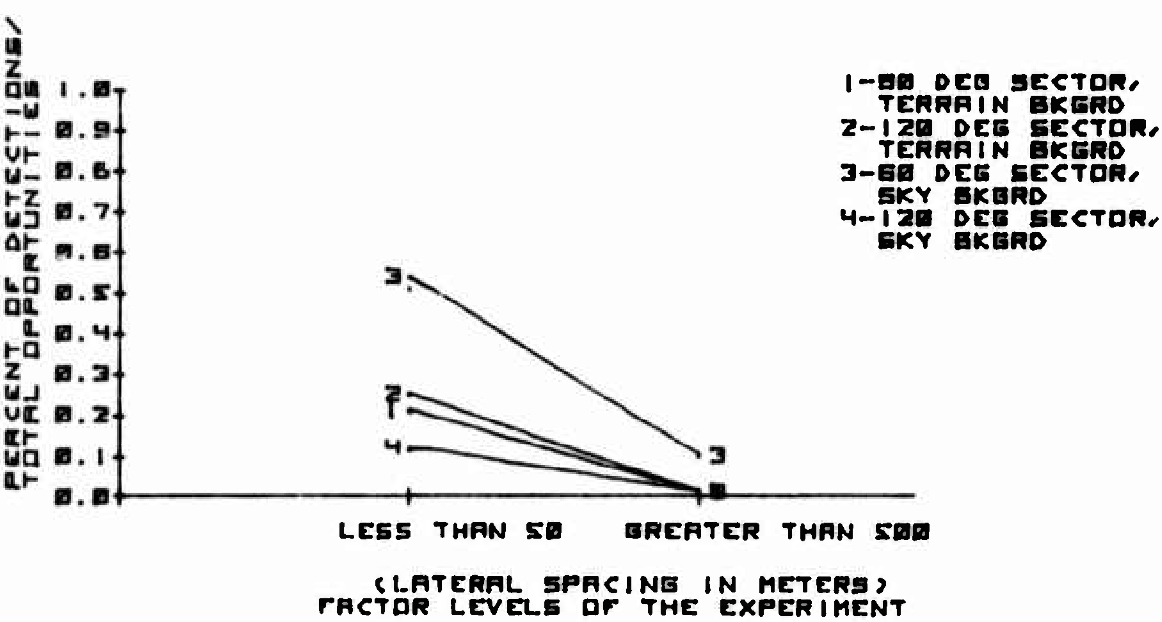


Figure 15. Effect of AHT lateral spacing on frequency of detection of both helicopters (solid lines denote significant differences; dashed lines denote nonsignificant differences)

1. 1,000 meters.

a. Against sky background there was no significant effect on frequency of detection due to search sector.

b. Against terrain background the frequency of detection decreased when observers used a 60° search sector.

2. 2,000 meters.

a. Against sky background there was no significant effect on frequency of detection due to search sector.

b. Against terrain background the frequency of detection decreased when observers used a 120° search sector.

3. 3,000 meters. With the exception of terrain background and lateral spacing less than 50 meters, the frequency of detection decreased when observers used a 120° search sector. For lateral spacing less than 50 meters against terrain background the factor search sector had no significant effect on frequency of detection.

4. Detection of both helicopters.

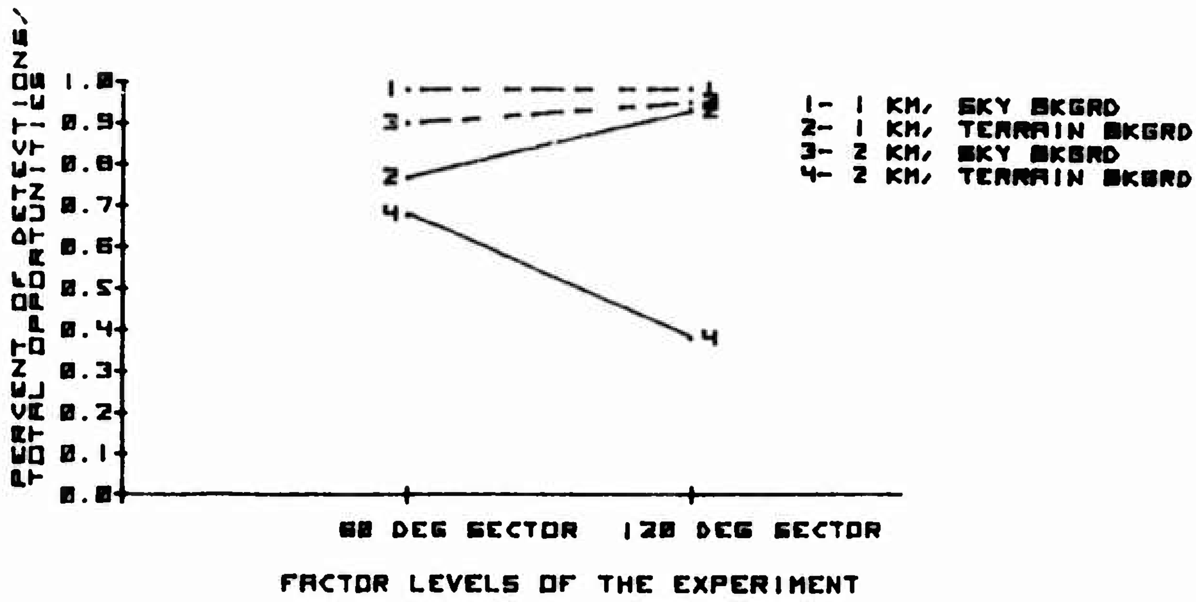
a. Against sky background the frequency of detection of both helicopters decreased when observers used a 120° search sector regardless of lateral spacing.

b. Against terrain background the factor search sector had no significant effect on frequency of detection of both helicopters.

5. Search sector. The quantitative effects of search sector on detection are shown in figures 16 and 17. Threat observers employing a 60° search sector consistently achieved more detections than in a 120° search sector with one exception. At 1,000 meters range with terrain background the wide (120°) search sector resulted in more detections. This result is not reasonable and is inconsistent with the other findings.

(d) EEA 5 (Effect of background on frequency of detection). The data used for this element of analysis are those of tables 15 and 16 with the exception of the no canopy trials.

1. The frequency of detection of at least one helicopter of the AHT decreased when against terrain background with one exception. When observers used a 120° search sector and the AHT was at



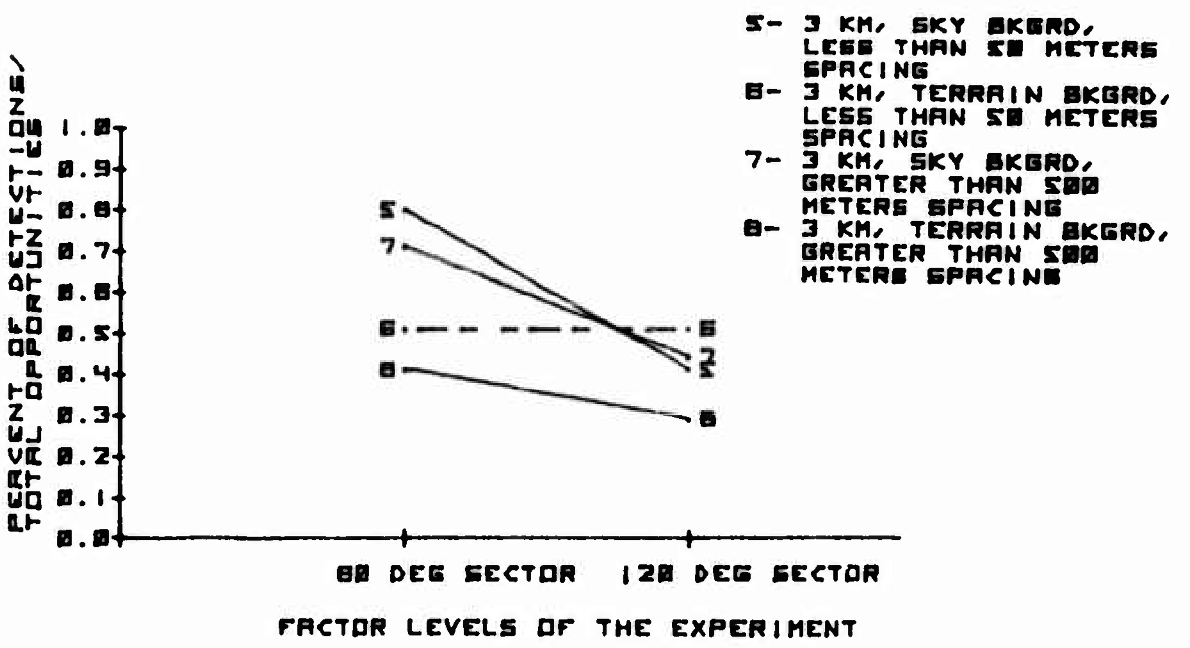


Figure 16. Effect of observer search sector on frequency of detection of at least one member of the AHT (solid lines denote significant differences; dashed lines denote nonsignificant differences)

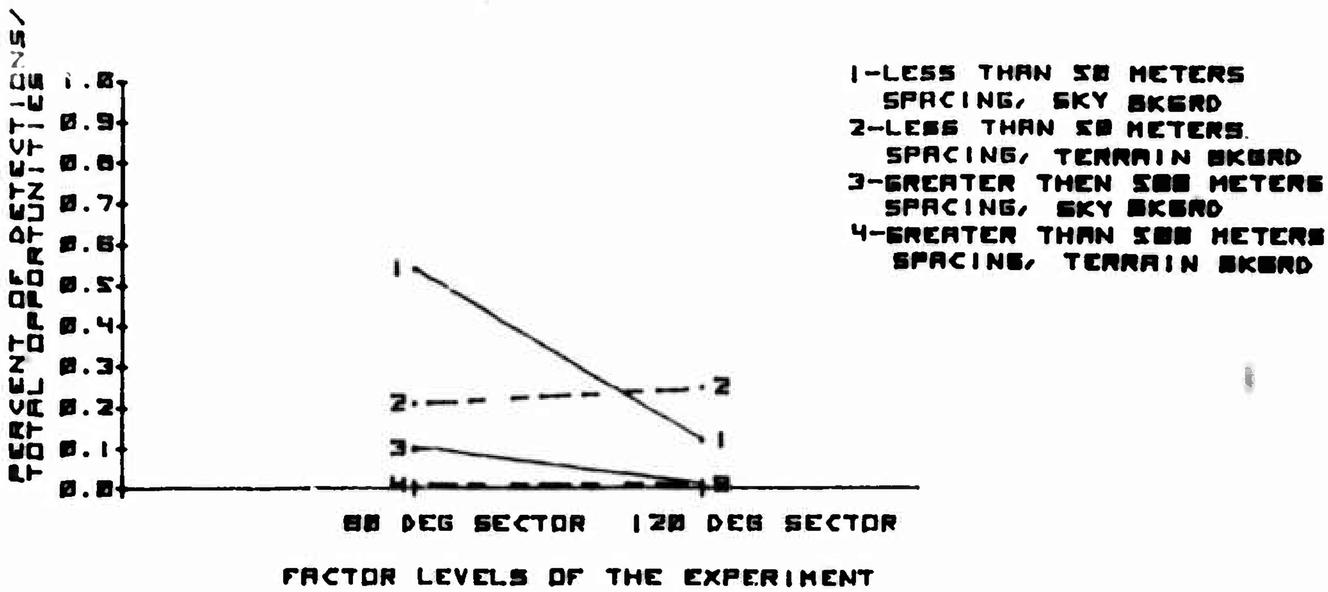


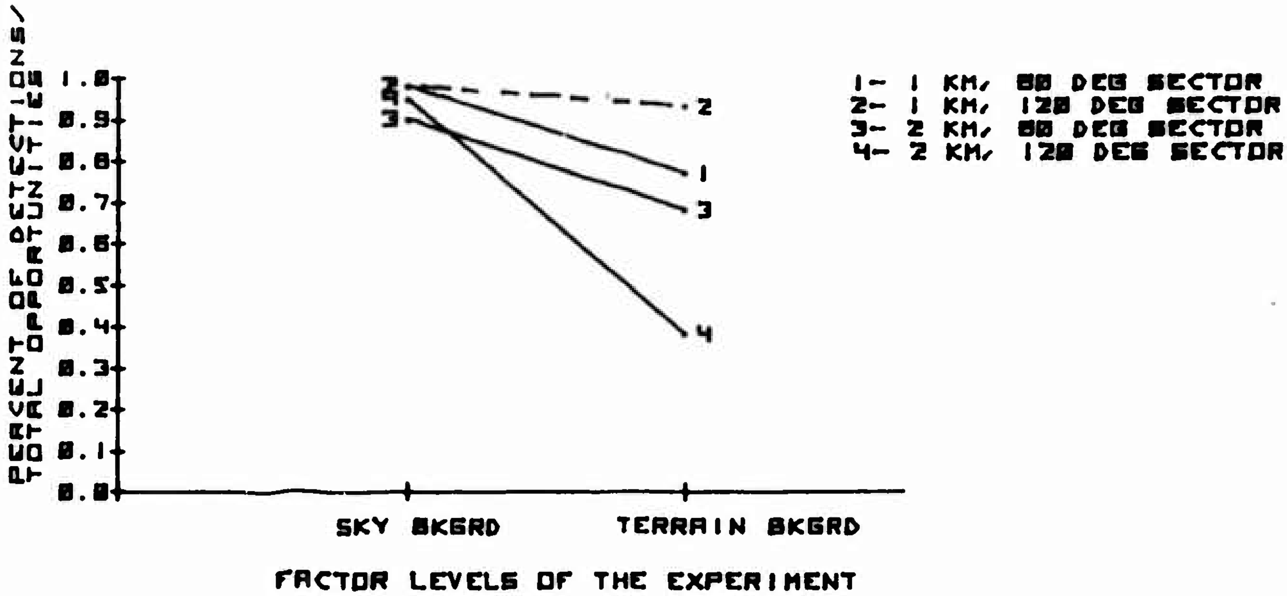
Figure 17. Effect of observer search sector on frequency of detection of both members of the AHT (solid lines denote significant differences; dashed lines denote nonsignificant differences)

3,000 meters range with close (<50) lateral spacing the frequency of detection decreased against sky background.

2. The frequency of detection when both helicopters were detected decreased when against terrain background. The exception to this was for 3,000 meters range, 120^{o} search sector, and lateral spacing less than 50 meters. Under these conditions the frequency of detection again decreased against sky background.

3. Figures 18 and 19 show the effect of background on AHT detectability. The general conclusion is that the frequency of detection is greater against sky than against terrain background. A qualification of this conclusion is the apparent inconsistency in results discussed in 1 and 2 above. This behavior could be due to an interactive effect of the known factors or be the result of the presence of unidentified or uncontrolled factors.

(e) EEA 9 (Effect of range on frequency of AHT detection). Data used to assess the effect of range were taken from table 15 where the AHT was equipped with canopies.



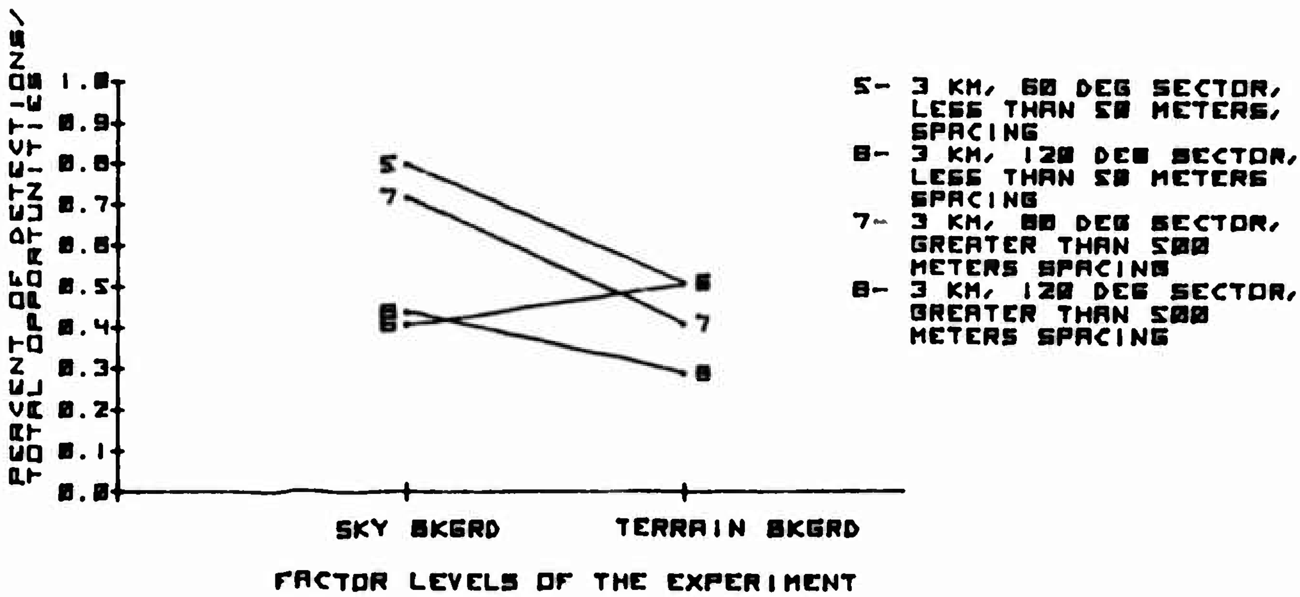


Figure 18. Effect of background on frequency of detection of at least one member of the AHT (solid lines denote significant differences; dashed lines denote nonsignificant differences)

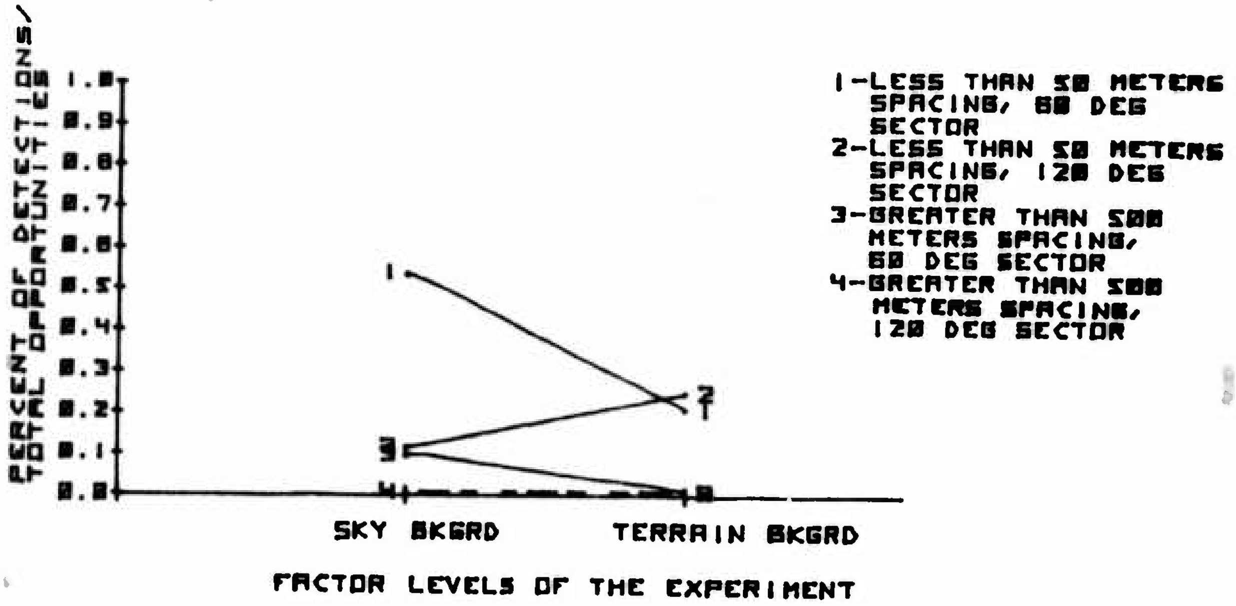


Figure 19. Effect of background on frequency of detection of both members of the AHT (solid lines denote significant differences; dashed lines denote nonsignificant differences)

1. The frequency of detection decreased as range increased regardless of the presence of other factors. This decrease was not significant in 25 percent of the trial conditions tested.

2. The quantitative effect of AHT to observer range is depicted in figure 20. It may be concluded that as range increases the ability of ground-to-air observers to detect the AHT significantly deteriorates. This is reasonable since apparent size of the helicopter decreases as a function of increasing range.

(2) Summary of factor effects on EEA.

(a) EEA 1. Canopy caused significant changes in detectability only when observers employed a narrow (60^{o}) search sector. With this search sector the absence of canopy resulted in a 78 percent decrease and a 16 percent increase in detections against terrain and sky background. With all trial conditions considered, the absence of canopies decreased frequency of detection an average 12 percent.

(b) EEA 3. Wide lateral spacing (>500 meters) decreased detectability only when the AHT employed terrain background. Against terrain background the wide lateral spacing resulted in a 31 percent

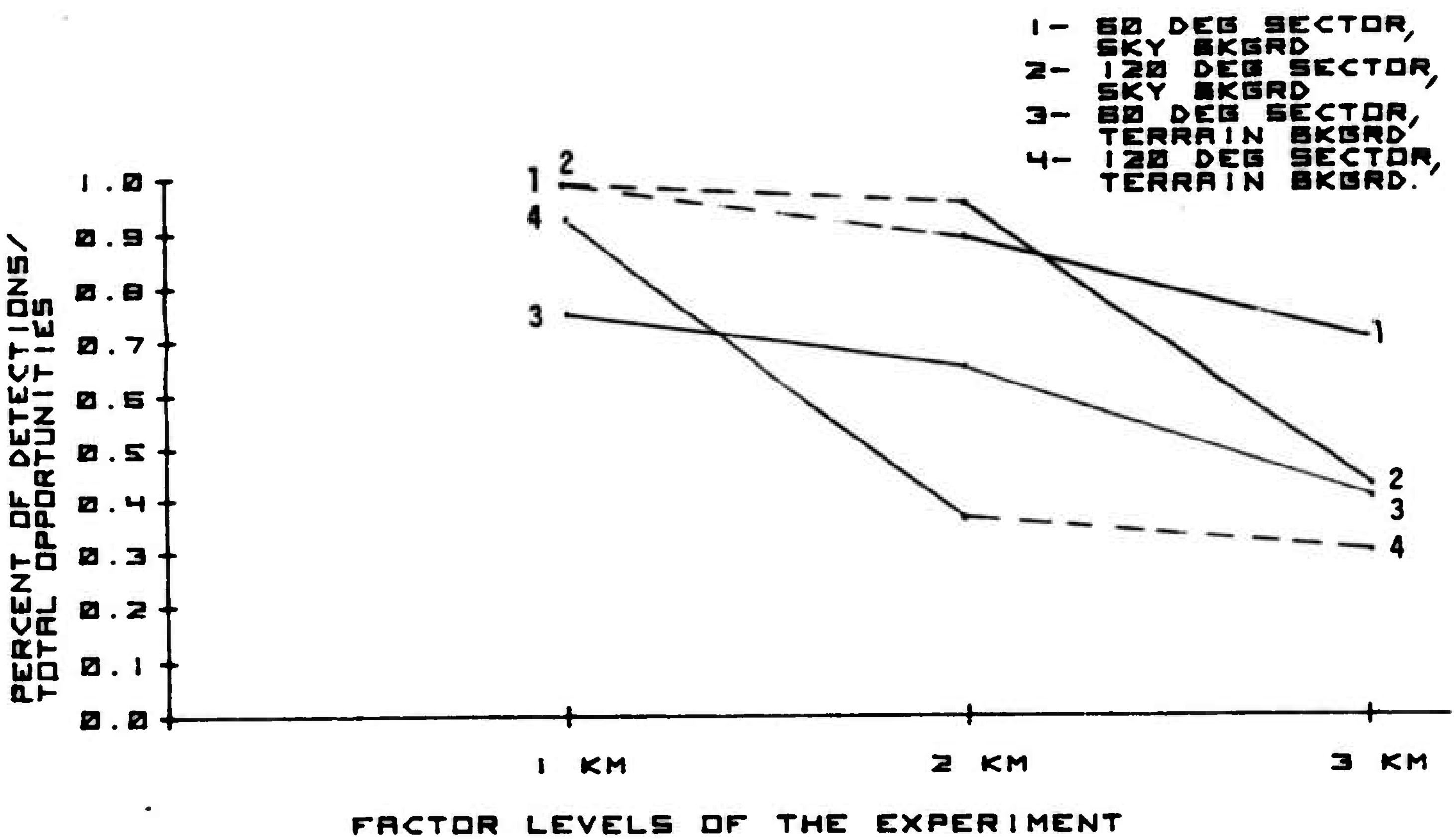


Figure 20. Effect of range on frequency of detection of at least one member of the AHT (solid lines denote significant differences; dashed lines denote nonsignificant differences)

decrease in frequency of detection. Across all trial conditions this decrease averaged 17 percent.

(c) EEA 4. Based on significant differences the 120^{0} search sector decreased frequency of detection an average of 28 percent. Throughout the AHT trials the 120^{0} search sector decreased frequency of detection an average 19 percent.

(d) EEA 5. Based on significant differences the effect of terrain background was to decrease frequency of detection an average 32 percent. When all trials are considered the average decrease was 33 percent. (The increase in percentage is due to the fact that without canopy trials were not tested for significance of background effect.)

(e) EEA 9. Range had the consistent effect of decreasing AHT detectability. The decrease in frequency of detection from 1,000 to 2,000 meters range (significant differences only) was an average 27 percent. From 2,000 to 3,000 meters range the similar decrease was an average 36 percent. Considered over all trials the frequency of detection decreased an average 20 percent from 1,000 to 2,000 meters and an average 49 percent from 1,000 to 3,000 meters range.

(3) Evaluation of AHT tactics.

(a) The independent factors considered in alternative AHT tactics were lateral spacing (at 3,000 meters only) and background. A total of six tactics were possible: two at 1,000 and 2,000 meters range and four at 3,000 meters range. Range and canopy are not considered tactics since:

1. Range is highly dependent on weapon system and deployment characteristics. In addition, it has already been demonstrated that frequency of detection is consistently lower at longer range.

2. The AH-1G or OH-58 cannot be deployed in a tactical situation without canopies. Were a technique available to simulate the absence of canopy, it would serve to decrease the frequency of detection (based on the findings of EEA 1).

(b) A preferred AHT tactic is the one that is optimal under the minimax criterion; i.e., the AHT should minimize the frequency of detection when the threat observers employ a search sector that maximizes their frequency of detection. The minimax decision matrix is table 17 where each row represents an alternative tactic. Along the right hand edge of this matrix are the maximum frequencies of detection for each tactic, and these determine the search sector that the threat observer would employ. For both search sector columns the

Table 17. Minimax decision matrix of the detection frequency of the AHT

Range	AHT Tactic	Lateral Spacing (meters)	Background	Threat Search Sector		AHT Minimax Tactic	Threat Maximin Tactic
				60^o	120^o		
1 km	V	250	Sky	.980	.975	VI	120^o
	VI	250	Terrain	.767	.925		
2 km	V	250	Sky	.900	.950	VI	60^o
	VI	250	Terrain	.680	.375		
3 km	VII	<50	Sky	.800	.406	X	60^o
	VIII	<50	Terrain	.511	.506		
	IX	>500	Sky	.717	.438		
	X	>500	Terrain	.409	.289		

minimum frequencies of detection are listed by range and represent the tactic the AHT should employ. The optimum tactics are those whose frequency of detection appears as a row maximum and column minimum.

(c) The optimal tactics under the minimax criterion are tactic VI at 1,000 and 2,000 meters and tactic X at 3,000 meters. The AHT should therefore use terrain background to the maximum extent possible and avoid lateral spacing appreciably less than 250 meters. It should be pointed out that these tactics are optimal regardless of threat search sector. This is so because the minimum frequencies of detection for a given range appeared as pairs for a specific tactic. An important consequence is that the AHT cannot depart from the optimum tactics (even with the knowledge of threat search sector) without suffering an increase in frequency of detection.

d. <u>Effect of Factors Across Systems</u>.

(1) EEA 1 - Canopy (AH-1G, OH-58, and AHT).

(a) Except for 60° threat search sector against sky background, the removal of canopy resulted in a significant decrease in frequency of detection.

(b) Against a sky background within a 60° search sector the frequency of detection increased significantly when the canopy was removed on the OH-58 and AHT. In these trials the most frequent detection cue was color contrast versus canopy glint. This fact might explain this apparent inconsistency.

(c) In general, a lower frequency of detection was achieved when the helicopter had no canopy to produce glint.

(2) EEA 2 - Lateral maneuver (AH-1G and OH-58).

(a) For all trial conditions except one, the frequency of detection significantly increased with lateral maneuver present. Against terrain background within a 60° search sector the frequency of detection of the OH-58 had no significant change due to lateral maneuver.

(b) In general, lateral maneuver increased the frequency of detection of the helicopter.

(3) EEA 3 - Lateral spacing (AHT).

(a) Lateral spacing greater than 500 meters resulted in a significant decrease in frequency of detection of at least one helicopter when the AHT was presented against terrain background and had

no significant effect on frequency of detection when the AHT was against sky background.

(b) Lateral spacing greater than 500 meters resulted in a significant decrease in frequency of detection of both helicopters irrespective of background or threat search sector.

(4) EEA 4 - Search sector (AH-1G, OH-58, and AHT).

(a) OH-58 and AHT (at least one helicopter detected), 1,000 meters.

1. Significant differences in frequency of detection due to search sector occurred only against terrain background. For the OH-58 the frequency of detection increased within a 60° search sector while for the AHT the frequency of detection decreased within the 60° search sector.

2. Against sky background the factor search sector had no significant effect on frequency of detection.

3. In general, the use by the ground force of a 120° search sector resulted in a decrease of detection of the helicopter.

(b) OH-58 and AHT (at least one helicopter detected), 2,000 meters.

1. The frequency of detection within a 60° search sector increased for the OH-58 helicopter irrespective of background.

2. For the AHT against sky background the factor search sector had no significant effect on frequency of detection. Against terrain background the frequency of detection increased within the 60° search sector.

(c) AH-1G and OH-58 at 3,000 meters.

1. Against terrain background the use of a 60° search sector increased the frequency of detection in three of the four conditions tested.

2. Against sky background the frequency of detection decreased within the 60° search sector for either the OH-58 or AH-1G (two of the four conditions).

3. Search sector had no significant effect in three of the eight conditions tested. In all of these three conditions the OH-58 or AH-1G employed lateral maneuver.

(d) AHT (at least one and both detected), 3,000 meters.

1. The frequency of detection increased within the 60^o search sector in five of the eight trial conditions tested. Of these five significant increases, four occurred against sky background and one against terrain background.

2. Search sector had no significant effect on frequency of detection in three of the eight conditions; all were against terrain background.

(e) OH-58 (at least one helicopter detected), 5,000 meters. Conflicting results were observed for the OH-58 at 5,000 meters range.

1. Against terrain background the frequency of detection increased within a 60^o search sector.

2. Against sky background the frequency of detection decreased within a 60^o search sector.

(5) EEA 5 - Background (OH-58, AH-1G, and AHT).

(a) OH-58 and AHT at 1,000 meters.

1. The frequency of detection increased against sky background in three of the four trial conditions.

2. Background had no significant effect on frequency of detection of the AHT within a 120^o search sector.

(b) OH-58 and AHT at 2,000 meters.

1. Frequency of detection increased against sky background for the AHT irrespective of search sector.

2. Frequency of detection decreased against sky background for the OH-58 within 60^o search sector. Within a 120^o search sector the factor background had no significant effect on frequency of detection.

(c) AH-1G and OH-58 at 3,000 meters.

1. The frequency of detection significantly increased against sky background in five of the eight trial conditions. All of these increases occurred when the helicopter performed lateral maneuver.

2. Within a 60° search sector using no lateral maneuver, the frequency of detection decreased against sky background for the OH-58.

3. Background had no significant effect on frequency of detection in two of the eight trial conditions.

(d) AHT at 3,000 meters (at least one and both detected).

1. The frequency of detection significantly increased against sky background in four of the six trial conditions.

2. In two of the six conditions the frequency of detection significantly decreased against sky background. Both cases were for the AHT with lateral spacing less than 50 meters within a 120° search sector.

(e) OH-58 at 5,000 meters.

1. The frequency of detection increased against sky background within 120° search sector and decreased against sky background within the 60° search sector.

2. No general conclusion can be reached about the general effect of background on frequency of detection for the OH-58 at 3,000 meters range.

(f) In general, the terrain-conducted trials resulted in a lower frequency of detection.

(6) EEA 6 - Change of position (OH-58 and AH-1G).

(a) The frequency of detection significantly decreased when the helicopter changed position in four of the eight trial conditions.

(b) This frequency significantly increased when the OH-58 changed position within a 120° search sector and used a 30-second time between pop-ups (this anomaly is unexplainable).

(c) Change of pop-up position had no significant effect on frequency of detection in three of the eight trial conditions. All of these three were for the AH-1G helicopter.

(7) EEA 7 - Time between pop-ups (OH-58 and AH-1G).

(a) The frequency of detection significantly decreased with a 60-second interval between pop-ups in three of the eight trial conditions. All of these occurred for the AH-1G.

(b) When using same pop-up position within a 120^{o} search sector, the frequency of detection increased for a 60-second interval between pop-ups for the OH-58.

(c) Time interval between pop-ups had no significant effect on frequency of detection in four of the eight trial conditions. In three of these four the helicopter changed pop-up position.

(d) In general, a single helicopter has its lowest frequency of detection when the time between pop-ups is 60 seconds and the pop-up position is relocated.

(8) EEA 8 - IR suppressant paint (OH-58). The IR painted helicopters were detected with a significantly lower frequency of detection.

(9) EEA 9 - Range (OH-58, AH-1G, and AHT).

(a) The frequency of detection decreased with range in 12 of the 20 trial conditions and had no significant effect on frequency of detection in seven of the 20 trial conditions.

(b) The only significant increase in frequency of detection occurred for the OH-58 against terrain background within a 120^{o} search sector from 1,000 to 2,000 meters.

(c) The general conclusion to be drawn from these findings is that increased range results in decreased frequency of detection of helicopters by ground observers.

e. Summary of Analysis of Effect of Tactics Upon the Frequency of Detection Across System.

(1) Table 18 summarizes the analysis previously conducted with regard to the effect of helicopter tactic upon the frequency of detection on the first pop-up.

Table 18. Summary of optimum helicopter tactics*

Range (km)	Optimum helicopter tactic (minimax criteria)		
	OH-58	AH-1G	AHT
1	I (NLM, T)		VI (NLM, T, 250)
2	III (NLM, S)		VI (NLM, T, 250)
3	III (NLM, S)	I (NLM, T)	X (NLM, T, >500)
5	I (NLM, T)		

* Abbreviations: NLM = no lateral maneuver, T = terrain background, S = sky background, 250 = 250 meter spacing, >500 = greater than 500 meter spacing

b. Table 19 summarizes the optimum tactics for the OH-58 and AH-1G helicopters with regard to frequency of detection on the second pop-up.

Table 19. Summary of optimum multiple helicopter tactics (second pop-up)

Range	Background	Optimum helicopter tactic (minimax criteria)			
		OH-58		AH-1G	
		Time	Position	Time	Position
3 km	Terrain	60 seconds	Change	30 seconds	Change

6. CONCLUSIONS.

a. OH-58 Helicopter. At a range of 3,000 meters, an OH-58 should be painted with infrared suppressant paint. The helicopter should not employ lateral maneuver and, if possible, should maintain a terrain background. Irrespective of time elapsed between pop-ups, the OH-58 should pop-up in a different position. These tactics are especially favorable when the threat force assumes a hasty defense (search sector of 120°). The detectability of an OH-58 decreases with increases in range.

b. AH-1G Helicopter, 3,000 meters. Irrespective of canopy system, the AH-1G should not employ lateral maneuver and, whenever possible, should maintain a terrain background. Irrespective of second pop-up position, the OH-58 should remain masked for 1 minute between first and second pop-ups. These tactics are especially favorable when the threat force employs a hasty defense.

c. AHT. The attack helicopter team should not be configured with canopies. Whenever possible, the AHT should maintain a terrain background while spaced greater than 500 meters apart. Greater distances from the threat force provide for lower detectability. These tactics are especially favorable when the threat force assumes a hasty defense.

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APPENDIX A

EXPERIMENTAL DESIGN MATRICES

1. This appendix outlines the experimental matrices conducted to address each of the MOE.

2. The first entry in the matrix cell is the proportion of trials resulting in a detection to total trials conducted. The second entry is the median detection time.

3. Certain cells are common to more than one experimental matrix.

Table A-1. Experimental matrices for canopy experiments (continued next page)

Search Sector

		60°		120°	
		w	w/o	w	w/o
Background	Sky	6/70 >65	21/69 >65	17/80 >65	16/70 >65
	Terrain	* 46/80 58.8	36/90 >65	* 33/79 >65	11/90 >65

OH-58 helicopter, 3000 meter range

Search Sector

	60°		120°	
	w	w/o	w	w/o
Background	27/70 >65	34/90 >65	37/59 38.7	27/89 >65
	* 37/80 >65	20/70 >65	* 8/100 >65	13/70 >65

AH-1G helicopter, 3000 meter range

* These frequencies are associated with the initial pop-up trials of the multiple pop-up tactic experiments.

Table A-1. Experimental matrices for canopy experiments (concluded)

Search Sector

		60°		120°	
		w	w/o	w	w/o
Background	Sky	43/60 35.2	50/60 38.4	35/80 >65	28/80 >65
	Terrain	45/110 >65	7/80 >65	26/90 >65	22/60 >65

AH-1G and OH-58 helicopter, 500 meter spacing (at least one helicopter detected)

Table A-2. Experimental matrices for the lateral maneuver experiments

		Search Sector			
		60^0		120^0	
		W	W/O	W	W/O
Background	Sky	55/79 37.1	6/70 >65	57/80 32.3	17/80 >65
	Terrain	37/80 >65	* 46/80 52.8	32/79 >65	* 33/79 >65

OH-58 helicopter, 3000 meter range

		Search Sector			
		60^0		120^0	
		W	W/O	W	W/O
Background	Sky	78/100 21.9	27/70 >65	51/69 26.8	37/59 >65
	Terrain	48/79 32.7	* 37/80 >65	32/80 >65	* 8/100 >65

AH-1G helicopter, 3000 meter range

* These frequencies are associated with the initial pop-up trials of the multiple pop-up tactic experiments.

Table A-3. Experimental matrices for the lateral spacing experiments

Lateral Spacing

		<50		>500	
		60°	120°	60°	120°
Background	Sky	56/70 35.9	28/69 58.5	43/60 35.5	35/80 >65
	Terrain	46/90 61.0	40/79 >65	45/110 >65	26/90 >65

OH-58 and AH-1G helicopters (at least one helicopter detected)

Lateral Spacing

		<50		>500	
		60°	120°	60°	120°
Background	Sky	38/70 48.1	18/69 >65	6/60 >65	1/80 >65
	Terrain	19/90 >65	20/79 >65	1/110 >65	1/90 >65

OH-58 and AH-1G helicopters (both helicopters detected)

Table A-4. Experimental matrices for the background and search sector experiments

Range (Meters)

		1000		2000	
		60°	120°	60°	120°
Background	Sky	49/50 26.9	39/40 22.9	27/30 28.6	38/40 30.5
	Terrain	23/30 36.4	37/40 23.9	34/50 35.7	15/40 >65

AH-1G and OH-58 helicopters (at least one helicopter detected)

Range (Meters)

		1000		2000		3000		5000	
		60°	120°	60°	120°	60°	120°	60°	120°
kground	Sky	37/40 15.4	35/40 23.5	21/40 53.1	11/50 >65	6/70 >65	17/80 >65	11/79 >65	22/89 >65
	Terrain	19/40 >65	9/40 >65	28/40 33.6	6/30 >65	*46/80 58.8	*33/79 >65	19/80 >65	2/70 >65

OH-58 helicopter

* These frequencies are associated with the initial pop-up trials of the multiple pop-up tactic experiments.

Table A-5. Experimental matrices for the pop-up tactic experiments

Elapsed Time

Position		30 seconds		60 seconds	
		60^0	120^0	60^0	120^0
Position	Same	46/80 36.7	11/80 >65	53/80 19.5	44/79 34.3
	Change	34/80 >65	25/80 >65	26/80 >65	31/80 >65

OH-58 helicopter, 3000 meter range, terrain background

Elapsed Time

Position		30 seconds		60 seconds	
		60^0	120^0	60^0	120^0
Position	Same	44/80 38.1	28/80 >65	26/80 >65	14/100 >65
	Change	18/70 >65	25/80 >65	27/80 >65	17/79 >65

AH-1G helicopter, 3000 meter range, terrain background

APPENDIX B

DECISION THEORY

1. Decision theory involves the identification and definition of objectives, courses of action, and uncontrolled variables. In addition, the construction of a measure of performance and a criterion of "best" measurement must be specified to determine the optimum alternatives. Three types of problems arise within decision theory: (1) certainty - each course of action is believed to result in only one outcome, (2) risk - each course of action is believed to result in alternate outcomes and the probabilities of each are known or can be estimated, and (3) uncertainty - each course of action results in outcomes unknown and thus cannot be assigned probabilities to the possible outcomes.

2. For convenience, the problem is depicted as a payoff matrix in which each column represents an uncontrolled condition (e.g., search sector that a threat force is able to employ) and each row represents a potential course of action (e.g., alternate helicopter tactics). See table B-1. The courses of action and conditions form mutually exclusive and exhaustive sets for purposes of interpretation. The entries within each cell represent utilities/disutilities of outcomes to the decision maker. One of several criteria for selecting a particular course of action is called the minimax (maximin) decision criterion. The decision maker attempts to minimize his maximum losses while the conditions (selected by an opposing decision maker) are chosen so as to maximize the opponents minimum gain.

Table B-1. Payoff matrix

		Uncontrolled conditions	
		C_1	C_2
Course of action	T_1	P_{11}	P_{12}
	T_2	P_{21}	P_{22}
	T_3	P_{31}	P_{32}
	T_4	P_{41}	P_{42}

3. Reference table B-2 and assume that tactics I through III are candidate tactics for helicopter deployment and the threat search sectors are 60° and 120°, respectively. The measures of performance (disutility) are the frequencies of detection of the helicopter by the threat force searching either a 60° or 120° sector. The probability of each search sector being employed is ascertainable through intelligence sources. It is evident that the problem in this example is a risk-type problem. Two assumptions are in order: (1) the probability that threat force will employ either search sector is 0.50, and (2) all candidate tactics are equally cost-effective.

Table B-2. Minimax decision matrix

		Threat search sector		
		60°	120°	Minimax
Candidate tactics	I	.57	.34	.57
	II	.45	.40	.45
	III	.78	.21	.78
	Maximin	.45	.21	

4. The minimax detection frequencies indicate that tactic II is most favorable. The 60° search sector is designated most favorable by the maximin detection frequencies. In this problem the minimax disutility equals the maximum disutility. This equality denotes the solution of the problem and the disutility of .45 frequency of detection is called a saddle point. (There exists no higher value in its row and no lower value in its column.) The significance of the saddle point is that the two corresponding strategies are "optimum" for each decision maker in the sense that he exercises the "best of all worst situations." Departure from the saddle point for either of the decision makers results

a greater loss. Instances in which the payoff matrix does not result in a saddle point allow the decision makers to employ a mixed strategy; that is, the strategy is dependent on the condition that exists.

APPENDIX C

DISCREPANCIES BETWEEN THE CDEC FINAL REPORT AND THE COAD ANALYSIS REPORT

1. GENERAL. The analysis methodologies were different for the two reports. The results and conclusions reached by CDEC were based upon the statistical technique of analysis of variance (ANOVA). Not being able to satisfy the assumptions of ANOVA (using the same transformation performed by CDEC), the COA analysis is based upon Fisher's exact probability test. The following paragraphs present concurrences or discrepancies existing within the two reports with regard to experimental factors. Although the two methodologies resulted in specific differences, the overall effect was not significant with regard to the conclusions.

2. CANOPY CONFIGURATION.

a. CDEC found that canopy configuration was not a significant factor upon the detectability of the AH-1G. COA analysis concurs.

b. CDEC results show that the OH-58 is less detectable without canopy against a terrain background and its detectability is non-significant against a sky background. COA analysis was inconclusive for the OH-58 canopy configuration.

c. CDEC found the AHT canopy configuration to be nonsignificant. The COA results found that the AHT tends to decrease its detectability without canopy.

3. LATERAL MANEUVER TACTIC. CDEC found that the lateral maneuver increased detection significantly for both the AH-1G and OH-58, except that lateral maneuver had a nonsignificant effect upon the detectability of the OH-58 against a terrain background. COA analysis found that lateral maneuver increased detection in all instances.

4. BACKGROUND.

a. The CDEC report shows that with regard to the OH-58 background is highly dependent on range and search sector. COA analysis concurs with this finding.

b. The CDEC results found one or a combination of AHs decreased its detection against a terrain background. COA analysis agrees with this finding.

5. LATERAL SPACING (<50 METERS VERSUS >500 METERS). CDEC found that lateral spacing was a nonsignificant factor with regard to AH detection. COA analysis results indicate that spacing of 500 meters or more decreases detection.

6. SEARCH SECTOR.

a. CDEC found that search sector was not a significant factor with regard to the detectability of the AH-1G. COA analysis shows that the 120^o search sector generally decreases detection.

b. CDEC results also show that the OH-58 is detected more frequently when it is against a terrain background when the threat is observing a 60^o search sector. Against a sky background, sector is nonsignificant. COA analysis shows that the 120^o sector generally decreases detection.

c. CDEC found the AHT's detectability increases when it is against a sky background if the threat searches a 60^o sector. Against a terrain background, sector is nonsignificant. COA analysis shows that the 120^o sector generally decreases detection.

7. TIME BETWEEN POP-UP (30 SECONDS VERSUS 60 SECONDS). The CDEC report found that the time between pop-ups was not a significant factor with regard to the detectability of the AH-1G and OH-58. The COA results agree with the findings only with regard to the OH-58. The AH-1G detectability was decreased when the elapsed time was 60 seconds.

8. RELOCATION. CDEC results found that position relocation was nonsignificant for the AH-1G and OH-58; however, the threat employing a 60^o search sector detected the OH-58 more frequently when the AH popped up in the same location. The COA analysis agrees with the CDEC finding regarding the AH-1G; however, position relocation for the OH-58 decreased its detectability.

9. INFRARED (IR) SUPPRESSANT PAINT. The CDEC and COA analysis reports concur that the IR paint decreases detection.

10. CONCLUSIONS.

a. OH-58. The CDEC report concluded that the AH: (a) should use IR suppressant paint, irrespective of canopy configuration; (b) should maintain a sky background; (c) should not employ lateral maneuver; and (d) irrespective of time between pop-ups, should choose a different location for the second pop-up. These tactics would especially be favorable when the threat employs a 120^o search sector. COA analysis

concurs with this assessment in its entirety except that the OH-58 should attempt to maintain a terrain background.

b. AH-1G. The conclusion with regard to the AH, according to CDEC analysis, is that: (A) the AH, irrespective of canopy configuration and background, should not employ lateral maneuver; and (b) the AH experiences no significant decrease in detection with regard to time elapsed and position relocation of the second pop-up. These tactics are espectially favorable when the threat searches a 120° sector. COA analysis concluded that: (A) the AH, irrespective of canopy configuration, should not employ lateral maneuver and whenever possible should maintain a terrain background; and (b) irrespective of position relocation, the AH should remain masked for 60 seconds.

c. AHT. CDEC concluded that the AHT, irrespective of canopy configuration, should be spaced greater than 500 meters apart and should maintain a terrain background. COA agrees with this conclusion.

APPENDIX D

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